JUTE AND LINEN WEAVING

PART II.

CALCULATIONS AND STRUCTURE OF FABRICS.

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PREFACE.

IN presenting this, our second joint work to the public, we desire to record our hearty appreciation of the favourable reception and support accorded our first volume on the Mechanism of Jute and Linen Weaving.

In our positions, first as practical men and then as teachers, we have long felt the need of a comprehensive treatise on the mathematical side of the subject; and, in our endeavour to supply this want, we have, naturally, introduced matter which is of general interest to all engaged in the textile industries. The individual examples in yarn and cloth calculations certainly apply more directly to jute and linen goods than to those composed of the other fibres; but the chapter on the theory of the structure of fabrics, in which we claim a certain amount of originality, should be of special interest to every textile student and expert.

A reasonable amount of care has been bestowed on the examples, still it is quite possible that some errors may have crept in; if any such are noticed, we should be pleased to have our attention drawn to the fact.

We trust that this little volume may be received as favourably as its predecessor.

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CHAPTER I.

YARN COUNTS.

TO facilitate all calculations in connection with the composition of fabrics it is essential to have some recognised method of expressing in a simple manner the sizes or weights of the different yarns in use. This invariably consists in using the ordinary numerals either to express in multiples of some definite measure the length of such yarn contained in a standard or fixed weight, or to express the weight, in multiples of a fixed unit, of a certain length of the yarn. In either case the figure or figures applicable in any particular example are termed indifferently the "count," the "number," the "grist," or the "size" of that particular yarn.

Of the two methods the former is by far the more widely adopted, since it is applied to linen, cotton, woollen, worsted, and spun silk yarns, whereas the latter—which is in many respects the simpler and more rational of the two—is practically confined to jute and flax yarns. In the former system it is obvious that the number or count of the yarn must increase as the thickness of the yarn itself decreases, since a decrease in the cross section or weight of the yarn must mean that an increase of length, or of multiples of the under-

stood measure of length, will be required to balance the fixed weight. This inverse method usually forms a difficulty for the beginner, who naturally expects to find that as the yarn increases in weight its count will increase likewise. It also forms a greater difficulty when the question of twisted counts is considered.

Further complication arises when it is understood that although the same system of yarn counts is adopted in principle for cotton, linen, spun silk, woollen, and worsted yarns, yet in each of these industries—with the exception of cotton and silk, which adopt the same basis—a different unit of length is used, termed variously a "hank," "lea," or "skein." Raw silk yarns are treated in both manners, sometimes by stating the length in a fixed weight, and at others by indicating the weight of a fixed length. In the majority of cases, where the weight is fixed, the pound avoirdupois or the British unit of weight is chosen; but in others the ounce, the dram, and the grain, as well as such weights as 24oz., 26oz., 6lbs., and 24lbs. are in use.

When the difficulties involved by the use of the above diverse methods of counting are considered, it is not surprising to find that many suggestions have been made with a view to obtaining some uniform method of counting all yarns, and we see no reason why some such method should not be established for each particular industry, or even for a group of industries. The formation of any system intended to embrace the whole range of yarns is, however, scarcely practicable, for a close examination of the existing conditions will show that any such change would involve many difficulties. Any system which has for its object the simplification

of calculations is worthy of consideration, but to be of practical value such a system should be capable of expressing, between unity and three figures, the counts of all yarns in common use. To express a count in a fractional or a decimal number would undoubtedly lead to confusion, while high numbers—unless in multiples of 10—would be troublesome.

In this respect the present systems of counting, despite their many shortcomings, are unique, for in many cases one figure, and in the majority of cases two figures, is sufficient to express the counts of the yarns in general use. Were a uniform system to be adopted in the United Kingdom, it is obvious that the most rational method would be one whose unit of length was 1, 10, 100, or 1,000 yds. The latter length has already been suggested as the unit, with 1lb. avoirdupois as the unit of weight, and the number of such units of length in the above 1lb. weight to represent the count of the yarn. At first sight this appears to be a reasonable suggestion, but when applied to jute yarns it is found to be most unsuitable. Many of the heaviest yarns used in weaving are spun from the jute fibre, and the range of counts extends from 2's to 400's—*i.e.*, between 2lbs. and 400lbs. per spyndle of 14,400 yds. Applying the above suggested uniform count, the 2lb. yarn would be $\frac{14{,}400 \text{ yds.}}{2\text{lb.} \times 1{,}000 \text{ yds.}} \doteq 7\frac{1}{5}$ count for the finest yarn of this class; while the 400lb. yarn would be $\frac{14{,}400 \text{ yds.}}{400\text{lbs.} \times 1{,}000 \text{ yds.}} = \frac{9}{250}$ count for the coarsest yarn—results which are evidently absurd. It is true that by changing the length of the spyndle a more reasonable

result would be obtained, but in any case 1,000 yds. as unit would be quite unsuitable for this fibre.

Other systems suggested, such as yards per dram or yards per ounce, while suitable for certain yarns, would be found equally unsuitable when applied to yarns of other fibres. Neither must it be overlooked that any change of this kind would not simply be a variation of the calculations used in spinning and weaving, but that in many cases it would affect machinery as well. The "reel" of reeled yarn would also require to adapt itself to the new conditions were the change to be ideal.

Woollen and raw silk yarns are practically the only two classes for which different methods of counting are adopted in different districts; and were these districts to adopt a uniform system for their particular kind of yarn, we think there would then be little cause for complaint. While two systems of counting are in use for yarns spun from the flax fibre, they are both general in the districts where such yarns are in use, and serve to suitably distinguish between those yarns which have been spun dry and those which have been spun wet.

We are of opinion that, were it possible to overcome the difficulties of machinery, a rearrangement of the systems of counting yarns would ultimately be beneficial. At the same time we believe that it is practically impossible to obtain a satisfactory result by one single change. We therefore suggest that while for the finer classes of yarns the above-mentioned 1,000 yds. unit might form a suitable length, the unit for the coarser yarns must of necessity be much shorter; a 100 yds.

unit, and in some cases a 10 yds. unit, would be much more practical. The above remarks refer to the method based on a varying length and a fixed weight. A still better method would, in our opinion, be to adopt some such decimal system having a fixed length, and a weight which increased in proportion to the sectional area of the yarn, such as drams per 100 yds. for jute and flax yarns, and drams per 1,000 yds. for cotton, linen, silk, woollen, and worsted.

Jute Yarns.—These yarns may be received in one or other of the following conditions :—

1. Wound on to large warper's or dresser's bobbins, or into rolls or cheeses for the dressing bank.
2. In chains or warps.
3. In cops.
4. Reeled and bundled in hank form.

In every case the count of the yarn is determined by the weight in pounds avoirdupois of a spyndle of 14,400 yds. Thus, if a spyndle weighs 7lbs., the yarn is termed 7lb. yarn, or 7's simply, and so on. If the yarn is reeled, it is treated according to the following table, which is also used for dry-spun flax yarns :—

YARN TABLE FOR JUTE AND DRY-SPUN FLAX AND TOW YARNS.

90in. or the circumference of reel	=	1 thread	=	2½yds.
120 threads	=	1 cut or lea	=	300 ,,
2 cuts	=	1 heer	=	600 ,,
6 heers..........................	=	1 hank	=	3,600 ,,
4 hanks	=	1 spyndle	=	14,400

Yarns of the finer sizes may be sold either by the spyndle or by the pound, while heavy yarns are generally quoted per pound, and in many extra heavy sizes per ton weight, *e.g.* :—

7lb. warp in bundle	at 1s. 4½d, per spyndle.
8lb. cops	at 1s. 4¾d. ,,
9lb. warp in chains	at 2⅝d. per pound.
40lb. common weft	at 1¼d. ,,
200lb. rove in chain	at £9. 10s. per ton.

Dry-spun flax and tow yarns are for various reasons almost invariably reeled, and are made up on the basis of the above table, and, like jute yarns, the size or count is indicated by the weight in pounds of a spyndle of 14,400 yds—*e.g.*, if a spyndle weighs 2¼lbs., it is termed 2¼lbs. yarn, or 2¼'s simply, and so on. Such yarns are invariably sold by the spyndle, as for example :—

2½lb. flax warp	at 1s. 9½d. per spyndle.
4lb. tow weft	at 1s. 10d. ,,

Wet-spun flax, or lea yarns, as they are generally termed, are usually reeled, but are made up and sold on a different basis from those of the dry-spun class :—

TABLE FOR WET-SPUN FLAX OR LEA YARNS.

90in. or the circumference of reel	=	1 thread....	=	2½yds.
120 threads	=	1 lea	=	300 ,,
12 leas......................	=	1hank,Scotch or Irish..	=	3,600 ,,
10 leas......................	=	1hankEnglish	=	3,000 ,,
16⅔ Scotch or Irish hanks .... / 20 English hanks	=	200 leas or 1 bundle ..	=	60,000 ,,

The count of the above yarns is determined by the number of leas of 300 yds. each which weigh 1lb. Thus, if 25 leas weigh 1lb., the yarn is termed 25's, and similarly

for all others. Lea yarns, whether line or tow, are invariably sold per bundle of 60,000 yds. Thus :—

32-lea line warp............	at 6s.	per bundle.
50-lea line weft	at 4s. 6d.	,,
25-lea tow weft	at 5s. 9d.	,,

Cotton yarns may be taken as being supplied in four general forms :—

1. Reeled and made up in bundles of 5lbs. or 10lbs. each.
2. In chains or in warps on beam.
3. In cops.
4. In rolls or cheeses.

When reeled, the following table is observed :—

TABLE FOR COTTON YARNS.

54in. or the circumference of reel	=	1 thread	=	1½yds.
80 threads..................	=	1 wrap or rap or lea	=	120 ,,
7 raps	=	1 hank	=	840 ,,
18 hanks	=	1 spyndle....	=	15,120 ,,

The count of cotton yarn is determined by the number of hanks of 840 yds. each which weigh 1lb. Thus, if 18 hanks weigh 1lb., the yarn is termed 18's. Cotton yarn is invariably sold by the pound—undoubtedly the most rational method of sale.

Testing Yarns for Correct Counts—In performing this function, it must be understood that the nominal or stated count of any yarn indicates its count in the original or spun condition, and not after the yarn may have been subjected to any processes of bleaching, dyeing, &c. If the yarn be received in the grey or spun condition, and in the form of hanks, probably the simplest method of testing the count of jute or of flax yarns is

to count off a spyndle and weigh it. But in many cases such a quantity is not available, and in such circumstances a simple method is to take three cuts, or the sixteenth part of a spyndle, and find the weight of this quantity in ounces. This weight in ounces will represent the weight of a spyndle in pounds, since the quantity weighed and 1oz. are each a sixteenth part of their respective units. If three cuts weigh $8\frac{1}{2}$ozs., the weight of one spyndle will be :—

$$\frac{8\tfrac{1}{2}\text{ozs.} \times 48 \text{ cuts per spyndle}}{3 \text{ cuts} \times 16\text{ozs. per pound}} = 8\tfrac{1}{2}\text{lbs. per spyndle.}$$

By taking three cuts calculation is saved ; but clearly any other quantity may be weighed, and the count or pounds per spyndle found by a similar calculation. For instance, if two heers of flax yarn (it is generally leased in heers of 240 threads each) weigh $3\frac{1}{4}$ozs., the count will be :—

$$\frac{3\tfrac{1}{4}\text{ozs.} \times 24 \text{ heers per spyndle}}{2 \text{ heers} \times 16\text{ozs. per pound}} = 2\tfrac{7}{16}\text{lbs. per spyndle.}$$

In treating the yarn in this manner it is presumed that the yarn is correctly reeled—*i.e.*, that each cut or heer contains its correct number of threads. This is not always the case, for sometimes the yarn is spun too heavy, and in order that the aggregate weight may be correct, the total length is reduced to some extent. This is usually obtained by having fewer threads per cut than the standard number 120. To check this it is necessary to count the threads in several cuts and find the average number. Let us assume that on counting six cuts of a nominal 8lb. yarn we obtained the following results : 118, 114, 121, 113, 116, and 120. The average of these is :—

$$\frac{118+114+121+113+116+120}{6}=117 \text{ threads};$$ and the true count of the yarn (assuming that the six cuts weighed exactly 1lb.) will be :—

$$\frac{1\text{lb.} \times 14{,}400 \text{ yds. per spyndle}}{6 \text{ cuts} \times 117 \text{ threads} \times 2\frac{1}{2} \text{ yds.}}=8{\cdot}2\text{lbs. per spyndle.}$$

The same result may be obtained by the direct method. Thus :—

$$\frac{8\text{lbs.} \times 120 \text{ threads}}{117 \text{ threads}}=8{\cdot}2\text{lbs. per spyndle.}$$

Suppose, however, that the 6 cuts weighed 17ozs., then the true counts would be :—

$$\frac{17\text{ozs.} \times 14{,}400 \text{ yds.}}{16\text{ozs. per lb.} \times 6 \text{ cuts} \times 117 \text{ threads} \times 2\frac{1}{2} \text{ yds.}}=8{\cdot}72\text{lbs. per spyndle};$$

or direct,

$$\frac{8\text{lbs.} \times 120 \text{ threads} \times 17\text{ozs.}}{117 \text{ threads} \times 16\text{ozs.}}=8{\cdot}72\text{lbs. per spyndle.}$$

This would mean that the yarn was :—

$$\frac{(8{\cdot}72\text{lbs.}-8\text{lbs.}) \times 100}{8\text{lbs.}}=9 \text{ per cent. over weight.}$$

Where yarns are received in chains, in cops, or on spools or rolls, a slight variation of method is necessary. If in chain the following particulars are usually given :—

1. The splits, two threads being termed a split, except in double warps, when there are four threads.

2. The length of chain in yards, or in ells of 37in.

3. The size or count of the yarn.

4. The weight.

These usually take the undernoted form :—

Chains	Splits	Ells	Yards	Size	Cwt.	Qr.	Lbs.
2	256	—	540	9lb.	3	0	20
1	195	360	—	8lb. D. W.	1	1	20

To find whether the above yarns are correct count it is necessary to divide the total weight in pounds by the quantity of yarn in spyndles, in order to find the weight per spyndle. Thus :—

$$\frac{\text{Weight in pounds}}{\text{Quantity in spyndles}} = \text{pounds per spyndle.}$$

In the first example of the above form of particulars:—

The weight $= [(3 \times 112) + 20]$ lbs. $=$ 356lbs.

The quantity =

$$\frac{\text{chains} \times \text{splits} \times \text{threads per split} \times \text{yards}}{\text{spyndle unit}} = \text{spyndles}$$

$$= \frac{2 \times 256 \times 2 \times 540}{14{,}400} = 38{\cdot}4 \text{ spyndles.}$$

$$\therefore \frac{\text{Weight in pounds}}{\text{Quantity in spyndles}} = \frac{356}{38{\cdot}4} = 9{\cdot}27\text{lbs. per spyndle.}$$

In the second case, which is double warp, as indicated by the letters D.W. immediately after the size of the yarn :—

The weight $= 112 + 28 + 20 =$ 160lbs.

The quantity =

$$\frac{1 \times 195 \times 4 \times 360 \times 37\text{in. per ell}}{14{,}400 \times 36\text{in. per yard}} = 20{\cdot}04 \text{ spyndles.}$$

$$\therefore \frac{160\text{lbs.}}{20{\cdot}04 \text{ spyndles}} = 7{\cdot}98, \text{ practically 8lbs. per spyndle.}$$

The above methods permit of considerable contraction,

but we shall refer to these more fully under warp calculations.

When the yarn is received in cop, or in any unmeasured condition, it is necessary to measure off a certain quantity by a small hand reel or by a patent reel for the purpose, to weigh accurately (in grains—7,000 per pound, if need be), and then calculate the weight per spyndle in pounds. Several tests from different spools or cops should be made, and the average taken to insure satisfactory results.

Suppose 120 yds. weigh 935 grains, the jute count, or the weight of the yarn per spyndle, will be :—

$$\frac{935 \text{ grains} \times 14{,}400 \text{ yds. per spyndle}}{120 \text{ yds.} \times 7{,}000 \text{ grains per pound}} = 16{\cdot}03 \text{ lbs. per spyndle.}$$

The explanation of the above formula is as follows : The weight (935) is first divided by the length taken in order to obtain the weight of 1 yd.; the quotient is multiplied by the spyndle unit, and this product is divided by the grains per pound, the final quotient giving the pounds per spyndle (16·03), as above.

Flax yarns are subject to the same rules as jute yarns, with the addition that it is often necessary to consider that the yarn has undergone some bleaching or a decolouring process, and that in such treatment it will have lost some of its original or spun weight. The proportion or percentage of loss varies very considerably with the quality of the yarn and with the extent to which the bleaching process has been carried. The actual loss can be determined by weighing the yarn before and after the bleaching process, and the percentage loss for any particular quality is found by calculation based on the facts thus obtained. Each manufacturer

should have such a table, applicable to his particular classes of yarn, compiled for his guidance.

The following table indicates several of the processes or stages through which flax and lea yarns are taken; it also shows an approximate loss per cent. for each :—

Boiled	4 to 8 per cent.
Twice Boiled	7 to 10 ,,
Creamed	8 to 12 ,,
Half Bleached	10 to 15 ,,
Full Bleached	12 to 25 ,,

In addition to the above common terms, many districts indicate intermediate stages by such terms as "duck," "changed," "quarter-white," and "three-quarter white."

Boiling the yarn in soda lye cleans and softens it (the same result is often obtained mechanically by fluted rollers), thus making it more workable in the weaving process. Boiling removes a considerable quantity of gummy substances from the yarn, and disposes of much dirt and woody matter adhering to the fibre at the end of the spinning process. It also decomposes the insoluble pectic acid and changes it into metapectic acid, which unites with the alkalies and forms a soluble compound. The action of bleaching proceeds slowly if much pectic acid remains, besides having a tendency to tender the fibre. Fine yarns intended to be bleached in the cloth condition are usually boiled. Creaming, in which the yarn is partly decolourised by the aid of bleaching powder, is resorted to for some fabrics which are to be sold in that condition, and in some cases for damasks which require to be further bleached. This latter procedure is pronounced by bleaching authorities to be illogical, since creamed yarn

is more difficult to decolourise (probably due to unremoved pectic acid) and more easily tendered by the further bleaching processes than yarn which is in the grey condition. Bleaching, or varying degrees of whiteness, is only resorted to for those yarns which require little or no bleaching in the cloth condition, weft yarn being often further treated than the warp yarn for the same fabric.

Cotton yarns are also regularly bleached, but, due to the difference in the chemical composition, as well as to the physical structure of the fibre, the loss in the bleaching of cotton is often only one quarter that of the loss in flax yarns. Jute yarns are generally woven in their natural colour, although some quantities are bleached and dyed.

Once the percentage of loss has been determined, the further calculation to find the count of the yarn is simple. If, for example, a hank of flax yarn which has lost 15 per cent. in bleaching weighs $8\frac{1}{4}$oz., its original count must have been :—

$$\frac{8\frac{1}{4}\text{oz.} : 4 \text{ hanks per spyndle} \times 100 \text{ per cent.}}{16\text{oz. per pound} \times 85 \text{ per cent.}} = 2{\cdot}43\text{lbs. per spyndle.}$$

Lea or wet-spun yarn requires a different method of calculation, as in this case the count of the yarn rises as the yarn itself decreases in weight. Since the count equals the number of leas of 300 yds. each per pound, obviously the simplest method of testing is to find the number of leas of the yarn which counterpoise this weight. If, however, small quantities only are available, the following formula applies :—

$$\frac{\text{Length in yards} \times \text{unit of weight}}{\text{Weight} \times \text{yards in unit of length}} = \text{count.}$$

If the length is not given in yards, it must be reduced to that term, and the weight must, of course, be expressed in the same terms in both numerator and denominator. Thus, if 2 leas of linen yarn weigh 310 grains, the count of the yarn will be :—

$$\frac{2 \times 300 \text{ yds.} \times 7{,}000 \text{ grains}}{310 \text{ grains} \times 300 \text{ yds.}} = 45{\cdot}16 \text{ leas per pound.}$$

One hank or 12 leas of creamed yarn which has lost 10 per cent. in creaming weighs $5\frac{1}{2}$ ozs., and it is required to find its lea count in the grey condition. Clearly, since the yarn has lost in weight and has decreased in actual size, its number will have increased from the grey to the creamed state in the proportion of 90 : 100. This must be corrected in the calculation by reducing the count in the proportion of 100 : 90. Thus :—

$$\frac{12 \times 300 \text{ yds.} \times 16 \text{oz. per pound} \times 90 \text{ per cent.}}{5{\cdot}5 \text{oz.} \times 300 \text{ yds.} \times 100 \text{ per cent.}} = 31{\cdot}42 \text{ leas per pound.}$$

In dividing the length of the portion taken by its weight, the length per unit of such weight is found.

$$\text{Thus :—} \frac{12 \times 300 \text{ yds.}}{5{\cdot}5 \text{ozs.}} = \text{yards per ounce,}$$

but yards per ounce $\times$ 16 = yards per pound, and this product divided by 300 yds. per lea = leas per pound.

Cotton yarn may be treated in the same way as lea yarns. Cotton, however, when made up in 5lb. or 10lb. bundles is readily checked. Thus, in 16's cotton, or 16 hanks per pound, there should be $16 \times 10 = 160$ hanks per 10lb. bundle. Any particular length may be treated according to the above rule—*e.g.*, a cotton warp of 1,600 ends, 500 yds, long, weighs 48lbs.; then the count of the yarn is :—

$$\frac{1{,}600 \times 500 \times 1 \text{lb.}}{48 \text{lbs.} \times 840 \text{ yds.}} = 19{\cdot}84 \text{ hanks per pound.}$$

Equivalent Counts.—It is always possible, and often needful, to find the count of a given yarn in the system of another. Thus, it is desired to find the lea number of a 2lb. flax and of an 8lb. jute yarn. Both of the latter counts are based upon the weight of a spyndle of 14,400 yds., in which there are 48 cuts or leas of 300 yds. each, while the former, or lea count, denotes the number of leas of 300 yds. per pound. If, therefore, in the flax case 48 leas weigh 2lbs., it is obvious that :—

$$\frac{\text{48 leas per spyndle}}{\text{2lbs. per spyndle}} = \text{24 leas per pound ;}$$

and in the jute case, $\frac{\text{48 leas}}{\text{8lbs.}}$ = 6 leas per pound. Therefore the lea numbers are 24 and 6 respectively. Conversely, it is clear that $\frac{\text{48 leas}}{\text{lea No.}}$ = pounds per spyndle, since 48 = pounds per spyndle × lea number.

If the yarns be lea and cotton, the method is different from the above, since both counts are based on a similar system, with a difference only in the units of length, that of the lea yarn being 300 yds., and the cotton being 840 yds. It is then necessary to bring the known count to yards per pound, and divide by the unit of length of the required count.

To convert a 56's lea into the equivalent cotton count, 56's lea = 56 × 300 = 16,800 yds. per pound.

$$\therefore \frac{56 \times 300}{\text{840 yds.}} = \text{20's cotton.}$$

Again, to bring 15's cotton into equivalent linen counts,

$$\therefore \frac{15 \times 840}{300} = \text{42's lea.}$$

TABLE I.—EQUIVALENT COUNTS: JUTE COUNTS AS BASIS.

Flax and Jute: Pounds per Spyndle, 14,400 yds.	Linen: Leas of 300 yds. per Pound.	Spun Silk and Cotton: Hanks of 840 yds. per Pound.	Worsted: Hanks of 560 yds. per Pound.	Woollen: Skeins of 256 yds. per Pound or Yards per Dram.
1	48·00	17·143	25·714	56·25
1¼	38·40	13·71	20·57	45·00
1½	32·00	11·43	17·14	37·50
1¾	27·43	9·79	14·69	32·14
2	24·00	8·57	12·86	28·12
2¼	21·33	7·62	11·43	25·00
2½	19·20	6·86	10·28	22·50
2¾	17·45	6·23	9·35	20·45
3	16·00	5·71	8·57	18·75
3½	13·71	4·89	7·34	16·07
4	12·00	4·28	6·43	14·06
4½	10·66	3·81	5·71	12·50
5	9·60	3·43	5·14	11·25
5½	8·73	3·12	4·67	10·23
6	8·00	2·86	4·28	9·37
6½	7·38	2·64	3·95	8·65
7	6·86	2·45	3·67	8·04
7½	6·40	2·29	3·43	7·50
8	6·00	2·14	3·21	7·03
8½	5·65	2·02	3·02	6·62
9	5·33	1·90	2·86	6·25
9½	5·05	1·80	2·71	5·92
10	4·80	1·71	2·57	5·63
10½	4·57	1·63	2·45	5·36
11	4·36	1·56	2·34	5·11
11½	4·17	1·49	2·24	4·89
12	4·00	1·43	2·14	4·69
13	3·69	1·32	1·98	4·33

Flax and Jute: Pounds per Spyndle, 14,400 yds.	Linen: Leas of 300 yds. per Pound.	Spun Silk and Cotton: Hanks of 840 yds. per Pound.	Worsted: Hanks of 560 yds. per Pound.	Woollen: Skeins of 256 yds. per Pound or Yards per Dram.
14	3·43	1·22	1·83	4·02
15	3·20	1·14	1·71	3·75
16	3·00	1·07	1·61	3·52
18	2·67	0·95	1·43	3·12
20	2·40	0·86	1·29	2·81
22	2·18	0·78	1·17	2·55
24	2·00	0·71	1·07	2·34
26	1·85	0·66	0·99	2·16
28	1·71	0·61	0·92	2·01
30	1·60	0·57	0·86	1·88
32	1·50	0·54	0·80	1·76
34	1·41	0·50	0·76	1·65
36	1·33	0·48	0·71	1·56
38	1·26	0·45	0·68	1·48
40	1·20	0·43	0·64	1·41
42	1·14	0·41	0·61	1·34
44	1·09	0·39	0·58	1·28
46	1·04	0·37	0·56	1·22
48	1·00	0·36	0·54	1·17
50	0·96	0·34	0·51	1·12
60	0·80	0·29	0·43	0·94
70	0·69	0·24	0·37	0·80
80	0·60	0·21	0·32	0·70
90	0·53	0·19	0·29	0·63
100	0·48	0·17	0·26	0·56
150	0·32	0·11	0·17	0·38
200	0·24	0·089	0·13	0·28
250	0·19	0·069	0·10	0·23
300	0·16	0·057	0·086	0·19
350	0·14	0·049	0·074	0·16
400	0·12	0·043	0·064	0·14

Jute and flax counts may be converted into equivalent cotton counts by the following formula :—

$$\frac{14{,}400}{\text{pounds per spyndle} \times 840 \text{ yds.}} = \text{cotton count.}$$

The equivalent cotton count of a 6lb. jute yarn =

$$\frac{14{,}400}{6 \times 840} = 2{\cdot}86\text{'s cotton.}$$

Tables I. and II. have been compiled to show at a glance the equivalent counts of jute, flax, lea, cotton, silk, woollen, and worsted yarns. Table I. shows the equivalent counts with respect to the ordinary jute and flax counts, while Table II. is compiled with reference to the ordinary lea counts.

The figures in Table I. are carried to two significant places of decimals ; in each case the last figure represents the nearest whole number above or below the actual value. The same remarks apply to Table II.

TABLE II.—EQUIVALENT COUNTS : LEA COUNTS AS BASIS.

Linen : Leas of 300 yds. per Pound.	Jute and Flax : Pounds per Spyndle, 14,400 yds.	Cotton and Spun Silk : Hanks of 840 yds. per Pound.	Worsted : Hanks of 560 yds. per Pound.	Woollen : Yards per Dram or Skeins of 256 yds. per Pound.
1	48·00	0·357143	0·535718	1·171875
2	24·00	0·71	1·07	2·34
3	16·00	1·07	1·61	3·52
4	12·00	1·43	2·14	4·69
5	9·60	1·79	2·69	5·86
6	8·00	2·14	3·21	7·03
8	6·00	2·86	4·29	9·38
10	4·80	3·58	5·36	11·72
12	4·00	4·29	6·43	14·06
14	3·43	5·00	7·50	16·41

Linen: Leas of 300 yds. per Pound.	Jute and Flax: Pounds per Spyndle, 14,400 yds.	Cotton and Spun Silk: Hanks of 840 yds. per Pound.	Worsted: Hanks of 560 yds. per Pound.	Woollen: Yards per Dram or Skeins of 256 yds. per Pound.
16	3·00	5·71	8·57	18·75
18	2·67	6·43	9·64	21·09
20	2·40	7·14	10·71	23·44
22	2·18	7·86	11·79	25·78
25	1·92	8·93	13·39	29·30
30	1·60	10·71	16·07	35·16
32	1·50	11·43	17·14	37·50
35	1·37	12·50	18·75	41·02
40	1·20	14·29	21·43	46·88
45	1·07	16·07	24·11	52·73
50	0·96	17·86	26·79	58·59
55	0·87	19·64	29·46	64·45
60	0·80	21·43	32·14	70·31
65	0·74	23·21	34·82	76·17
70	0·69	25·01	37·50	82·03
75	0·64	26·80	40·18	87·89
80	0·60	28·57	42·86	93·75
85	0·56	30·36	45·54	99·61
90	0·53	32·13	48·21	105·47
95	0·51	33·93	50·89	111·33
100	0·48	35·71	53·57	117·19
110	0·44	39·29	58·93	128·91
120	0·40	42·86	64·29	140·63
130	0·37	46·43	69·64	152·34
140	0·34	50·00	75·00	164·06
150	0·32	53·57	80·36	175·78
200	0·24	71·43	107·14	234·38
250	0·19	89·29	133·93	292·97
300	0·16	107·14	160·72	351·56
350	0·14	125·00	187·50	410·17
400	0·12	142·86	214·29	468·75

CHAPTER II.

TWISTED THREADS: RESULTANT COUNT AND COST.

YARNS are twisted or folded together for the purpose of imparting strength, durability, uniformity, or appearance. When the individual yarns comprising the twisted thread are all of the same fibre and count, the method of expressing the count of the twisted thread is common to all fibres except that of silk. Thus 6-ply 8's, 3-fold 60's, or simply 2/24's, indicate respectively that the twisted yarn consists of 6 threads of 8lb. jute, 3 threads of 60's linen, or 2 threads of 24's cotton, as the case may be. In silk, however, the count stated indicates the size of the yarn in its folded condition, and is, or at least ought always to be, expressed as 40's 2-fold, 20's 3-fold, or 40/2, 20/3, indicating that the thread is now 40's or 20's respectively, and that it is composed of two or three threads which result in one twisted thread of the count indicated. Jute yarns are regularly twisted from two to twelve or sixteen-fold, and in all cases, whether the yarns composing the twisted thread are alike in count or not, the same rule is observed for determining the twisted count.

RULE I.—*The resultant count when two or more yarns are twisted together is the sum of the counts of the individual threads if the contraction due to twisting is neglected.*

This rule is sufficiently clear, since it is obvious that if two threads which each weigh 5lbs. per spyndle are twisted together, the resultant thread must weigh $5+5=10$lbs. per spyndle. Jute yarns of different counts are not usually twisted together, but in any case the same rule applies. Similarly with dry-spun flax yarns, and all yarns the counts of which are based upon a fixed length with a varying weight. In cotton and in lea yarns, however, where the count is based upon a fixed weight and a varying length, a different rule is necessary.

RULE II.—*Given that the threads composing the twisted yarn are all of the same count, the resultant count is the quotient obtained by dividing the original count by the number of threads compounded.*

Thus $$3/60\text{'s} = \frac{60}{3} = 20\text{'s};$$

$$2/24\text{'s} = \frac{24}{2} = 12\text{'s}.$$

This rule is also evident, since, if we take 1lb. of 60's lea yarn, or $60 \times 300 = 18{,}000$ yds., and twist this into a three-fold yarn, we have $\frac{18{,}000}{3} = 6{,}000$ yds. of twist.

But $\frac{6{,}000 \text{ yds.}}{300 \text{ yds. per lea}} = 20$ leas of twist yarn per pound.

In the other case, 1lb. of 24's cotton $= 24 \times 840 = 20{,}160$ yds., and $\frac{20{,}160 \text{ yds.}}{2 \text{ threads}} = 10{,}080$ yds. of twist.

$$\therefore \frac{10{,}080}{840} = 12 \text{ hanks of twist per pound.}$$

Where, however, the more unusual practice obtains of

twisting together yarns of different counts, and in some cases of different materials, another method is necessary to determine the count of the compound thread. If the individual yarns are of different fibres it is first necessary to reduce each count to that system in which the twisted count is desired.

Example I.—In which the yarns are alike in fibre but different in count—*e.g.*, 1 thread of 20's lea and 1 thread of 10's lea are twisted together. What is the resultant count?

If contraction due to twist be neglected—and all such calculations are based upon this assumption—it is clear that the same length of each yarn will be required—*i.e.*, if we take 1lb. of 20's or $20 \times 300 =$ 6,000 yds., we must take the same length of the 10's yarn. Now, $\frac{6{,}000 \text{ yds.}}{300 \text{ yds. per lea}} = 20$ leas, and $\frac{20 \text{ leas}}{10 \text{ leas per pound}}$ $= 2$lb. of 10's yarn. $\therefore$ we require 2lb. of 10's yarn to twist with 1lb. of 20's yarn—*i.e.*, $2 + 1 = 3$lb. of twist. In this weight, however, there are 6,000 yds., or $\frac{6{,}000 \text{ yds.}}{300 \text{ yds. per lea}} = 20$ leas of twist.

$\therefore \ \frac{20 \text{ leas}}{3 \text{lbs.}} = 6\frac{2}{3}$ leas per pound or $6\frac{2}{3}$'s twist yarn.

Example II.—In which there are three different counts of yarn, say of the cotton fibre—*viz.*, 1 thread of 30's, 1 thread of 20's, and 1 thread of 10's. Again, assume that 1lb. of 30's and an equal length of 20's and 10's, or 30 hanks of each, are to be twisted together to produce 30 hanks of twist. Then

30 hanks of	30's cotton	$= \frac{30}{30}$	$=$	1lb.
30 ,,	20's ..	$= \frac{30}{20}$	$=$	$1\frac{1}{2}$lb.
30 ,,	10's ,,	$= \frac{30}{10}$	$=$	3lbs.
30 hanks of	twist cotton		$=$	$5\frac{1}{2}$lbs.

$\therefore \ \frac{30 \text{ hanks}}{5\frac{1}{2}\text{lbs.}} = \frac{30 \times 2}{11} = 5\frac{5}{11}$ hanks per pound, or $5\frac{5}{11}$'s twist cotton.

Example III.—Any number of threads may be treated in a similar manner—*e.g.*, if 1 thread of 40's, 1 thread of 20's, 1 thread of 10's, 1 thread of 8's, and 1 thread of 5's lea yarn be twisted together, find the resultant count.

In solving this example we shall assume that only one lea of each yarn is taken, and that the compounded threads form one lea of twist. Now,

	1 lea	of 40's	yarn	=	$\frac{1}{40}$lb.
	1 ,,	20's	,,	=	$\frac{1}{20}$lb.
	1 ,,	10's	,,	=	$\frac{1}{10}$lb.
	1 ,,	8's	,,	=	$\frac{1}{8}$lb.
	1 ,,	5's	,,	=	$\frac{1}{5}$lb.
$\therefore$	1 lea of twisted yarn			=	$\frac{20}{40}$lb., or $\frac{1}{2}$lb.

Hence,

$\frac{1 \text{ lea}}{\frac{1}{2}\text{lb. per lea}} = 2$ leas of twist yarn per pound, or the resultant count $= 2$'s.

The following rule to find the resultant count is deduced from these explanatory examples :—

RULE III.—*Divide any number by all the counts in succession, and again by the sum of the quotients thus obtained.*

In Examples I. and II. the highest count (which is generally to be preferred) has been utilised as the number, while in Example III. unity has been used as the common numerator.

The above rule can be expressed symbolically as follows : Let the counts of the different threads be

indicated by A, B, C, &c. Then

$$\frac{A}{\frac{A}{A}+\frac{A}{B}+\frac{A}{C}} \text{ or } \frac{B}{\frac{B}{B}+\frac{B}{C}+\frac{B}{A}} \text{ or } \frac{C}{\frac{C}{C}+\frac{C}{A}+\frac{C}{B}} =$$

twisted or resultant count;

or if N equals any number whatever,

$$\frac{N}{\frac{N}{A}+\frac{N}{B}+\frac{N}{C}+\frac{N}{D}, \text{ etc.,}} = \text{twisted or resultant count.}$$

Example IV.—Required the count of a compound thread composed of 1 thread of 40's lea, 1 thread of 15's cotton, and 1 thread of $1\frac{1}{2}$lb. of flax. 15's cotton $= \frac{15 \times 840}{300} = 42$ lea, and $1\frac{1}{2}$lb. flax $= \frac{48 \text{ leas}}{1\frac{1}{2}\text{lb.}} = 32$ lea. The three counts to be treated are therefore 40's, 42's, and 32's in the lea system; and applying the above rule we have

$$\frac{40}{\frac{40}{40}+\frac{40}{42}+\frac{40}{32}} = \frac{40}{1+\frac{20}{21}+\frac{5}{4}} = \frac{40}{\frac{84+80+105}{84}} =$$

$\frac{3,360}{269} = 12\frac{132}{269}$, the twisted lea count.

The same result would be obtained by substituting 42 or 32 for 40, or by taking the L.C.M. of the three numbers—*i.e.*, 3,360. Thus,

$$\frac{3,360}{\frac{3360}{40}+\frac{3360}{42}+\frac{3360}{32}} = \frac{3,360}{84+80+105} = \frac{3,360}{269} =$$

$12\frac{132}{269}$ counts, as above.

The following rule is more particularly applicable to cases where only two counts are compounded:—

RULE IV.—*The product of the two counts divided by the sum of the two counts equals the twisted count.*

$$\frac{\textit{Product of two counts}}{\textit{Sum of two counts}} = \textit{twisted count.}$$

Example V.—One thread of 10's cotton and one thread of 15's cotton are twisted together; find the resultant count by the above rule.

$$\frac{10 \times 15}{10 + 15} = \frac{150}{25} = 6\text{'s, the twisted count.}$$

This rule is simply a particular application of the previous rule. Since the number chosen for the dividend is the product of the two counts, it is evident that the sum of the quotients, found by dividing this number by the counts, must be the sum of the counts themselves. Thus, if 10lbs. of 15's cotton, in which there are $10 \times 15 = 150$ hanks, be twisted with 150 hanks of 10's cotton whose weight is $\frac{150}{10} = 15$lbs., the result will be 150 hanks of twist weighing $10 + 15 = 25$lbs.

$$\therefore \frac{150 \text{ hanks}}{25\text{lbs.}} = 6 \text{ hanks per pound, or 6's cotton.}$$

The above rule is also applicable in cases of three or more fold yarns by first finding the resultant count of any two of the yarns, and then compounding this result with the third and succeeding yarns.

Example VI.—Applying this to Example II., where one thread each of 30's, 20's, and 10's are compounded, we have $\frac{30 \times 20}{30 + 20} = \frac{600}{50} = 12$'s count.

Then

$$\frac{12 \times 10}{12 + 10} = \frac{120}{22} = 5\tfrac{5}{11}\text{'s twisted count, as in Example II.}$$

In some exceptional cases it is necessary to ascertain the size or count of a yarn which must be twisted with a given yarn in order to produce a certain count

of twist. It will be seen from Rule IV. that if A and B be two threads twisted together, and the resultant count is C, the relation between the three threads is as follows :—

$$\frac{A \times B}{A + B} = C,$$

from which we have

$$\begin{aligned} A\,B &= C\,(A+B) \\ A\,B &= A\,C + B\,C \\ A\,B - B\,C &= A\,C \\ B\,(A-C) &= A\,C \\ \therefore (1.) \qquad B &= \frac{A\,C}{A-C} \\ \text{Or } (2.) \qquad A &= \frac{B\,C}{B-C} \end{aligned}$$

Hence we have the following

RULE V. $\dfrac{\textit{Given count} \times \textit{twisted count}}{\textit{Given count} - \textit{twisted count}} = \textit{required count.}$

Example VII.—Let the given count be 10's and the twisted count 6's; then $\frac{10 \times 6}{10 - 6} = \frac{60}{4} = 15$'s, the required count.

When the individual threads of a twisted jute yarn are alike in size and price, the cost of the twisted thread is only altered by the amount charged for the operation of twisting. Thus, if 8lbs. single yarn costs $2\frac{3}{16}$d. per pound, the same yarn twisted in three or other fold will cost $2\frac{3}{16}$d. per pound plus the expense of twisting. Where, however, yarns of different sizes are twisted together, the price per pound of the twisted yarn may be found as follows :—

Example VIII.—Suppose a two-fold thread is composed of 8lb. yarn at $2\frac{1}{4}$d. per pound, and 10lb. yarn

at 2d. per pound, assuming that equal lengths (say one spyndle) of each are taken. Then,

1 spyndle of 8lb. yarn	= 8lb. at $2\frac{1}{4}$d.	= 18d. per spyndle.	
1 ,, 10lb. ,,	= 10lb. ,, 2d.	= 20d. ,,	
1 spyndle of twist	= 18lb.	= 38d. per spyndle.	

$$\therefore \frac{38\text{d.}}{18\text{lbs.}} = 2\tfrac{1}{9}\text{d. per pound,}$$

to which has to be added the expense of twisting.

Example IX.—A three-fold yarn is to be composed of 7lb. warp at 1s. 6d. per spyndle, 9lb. yarn at $2\frac{3}{16}$d. per pound, and $10\frac{1}{2}$lb. yarn at 2d. per pound. Then,

1 spyndle of 7lb. yarn	= 7lb. at 1s. 6d. per spl.	= 18d. per spl.	
1 ,, 9lb. ,,	= 9lb. ,, $2\frac{3}{16}$d. per lb.	= $19\frac{11}{16}$d. ,,	
1 ,, $10\frac{1}{2}$lb. ,,	= $10\frac{1}{2}$lb. ,, 2d. ,,	= 21d. ,,	
1 spyndle of twist	= $26\frac{1}{2}$lb.	= $58\frac{11}{16}$d. p. spl.	

$$\therefore \frac{58\frac{11}{16}\text{d.}}{26\frac{1}{2}\text{lb.}} = \frac{939}{16} \times \frac{2}{53} = \frac{939}{424} = 2\cdot 21\text{d. per pound.}$$

If the yarns be quoted per spyndle, it is obvious that the cost per spyndle of the twisted thread will be the sum of the various prices, plus, in every case, the cost of twisting. The same statement holds good with regard to flax yarns per spyndle, and to lea yarns when the latter are quoted per bundle of 60,000 yds.

The following general method is adopted to determine the cost of a twisted cotton thread when the yarns of which it is composed are different in count and price :—

Example X.—Suppose a three-fold yarn be composed of 6's cotton at 7d. per pound, 10's at 8d. per pound, and 15's at 9d. per pound.

RULE VI.—*The twisted count multiplied by the cost of a hank of the twisted yarn equals the cost per pound of the twisted thread.*

First find by Rule III. the twisted count :—

$$\frac{6}{\frac{6}{6}+\frac{6}{10}+\frac{6}{15}} = \frac{6}{\frac{30+18+12}{30}} = 6 \times \frac{30}{60} = 3\text{'s the}$$

twisted count. The cost of a hank of the twisted yarn will be $\frac{7\text{d.}}{6} + \frac{8\text{d.}}{10} + \frac{9\text{d.}}{15} = \frac{35+24+18}{30} = \frac{77}{30}\text{d.}$ per hank.

$\therefore \frac{77}{30} \times 3$ hanks per pound $= \frac{231}{30} = 7\frac{7}{10}$d. per pound.

Example XI.—A more complicated example might be stated as follows: Required the twisted cotton count and the price per pound of a three-fold yarn composed of 1 thread of 40's lea yarn at 4s. 6d. per bundle, 1 thread of 15's cotton at 9d. per pound, and 1 thread of $1\frac{1}{2}$lb. flax at 1s. $3\frac{3}{4}$d. per spyndle.

First, find the equivalent cotton count and the price per pound of 40's lea and $1\frac{1}{2}$lb. flax.

40's lea $\begin{cases} \dfrac{40 \times 300}{840} = 14\frac{2}{7} \text{ cotton count.} \\ \dfrac{54\text{d.} \times 40 \text{ leas per lb.}}{200 \text{ leas per bundle.}} = 10\frac{4}{5}\text{d. per pound.} \end{cases}$

$1\frac{1}{2}$lb. flax $\begin{cases} \dfrac{14{,}400 \text{ yds.}}{1\frac{1}{2}\text{lb.} \times 840 \text{ yds.}} = 11\frac{3}{7} \text{ cotton count.} \\ \dfrac{15\frac{3}{4}\text{d. per spyndle}}{1\frac{1}{2}\text{lb.}} = \dfrac{126}{12} = 10\frac{1}{2}\text{d. per pound.} \end{cases}$

We have therefore the following :—

15's cotton	at	9d.	per pound.
40's lea or $14\frac{2}{7}$'s	„	$10\frac{4}{5}$d.	„
$1\frac{1}{2}$lb. flax or $11\frac{3}{7}$'s	„	$10\frac{1}{2}$d.	„

$\therefore$ the twisted cotton count will be

$$\frac{15}{\frac{105}{105}+\frac{105}{100}+\frac{105}{80}}=\frac{15}{\frac{1}{1}+\frac{21}{20}+\frac{21}{16}}=\frac{15}{\frac{80+84+105}{80}}=$$

$$\frac{15\times 80}{269}=4\tfrac{124}{269} \text{ hanks per pound of twist.}$$

while the price per hank equals

$$\frac{9\text{d.}}{15}+\frac{10\frac{4}{5}\text{d.}}{14\frac{2}{7}}+\frac{10\frac{1}{2}\text{d.}}{11\frac{3}{7}}=\frac{3}{5}+\left(\frac{54}{5}\times\frac{7}{100}\right)+\left(\frac{21}{2}\times\frac{7}{80}\right)$$

$$=\frac{3}{5}+\frac{378}{500}+\frac{147}{160}$$

$$=\frac{9099}{4000}=2\tfrac{11}{40}\text{d. per hank.}$$

$$\therefore 4\tfrac{124}{269} \text{ hanks per pound} \times 2\frac{11\text{d.}}{40}=\frac{2730}{269}=$$

$$10\cdot 15\text{d. per pound.}$$

In the case of only two yarns the following method is applicable. Let A and B be the two counts.

RULE VII.—*Multiply the price per pound of A by the count of B, and the price per pound of B by the count of A ; the sum of these products divided by the sum of the counts gives the price per pound of the twisted thread.*

Example XII.—Find the cost per pound of a twisted thread composed of one thread of 6's cotton at 7d. per pound, and one thread of 10's cotton at 8d. per pound.

Here A and B are 6 and 10 respectively

$$\frac{(6\times 8)+(10\times 7)}{6+10}=\frac{118}{16}=7\tfrac{3}{8}\text{d. per pound.}$$

The above rule may also be applied to three or more fold yarns by treating them in stages as demonstrated in Example VI.

Example XIII.—One thread each of 6's, 10's, and 15's cotton at 7d., 8d., and 9d. per pound respectively

are twisted together; find the price per pound of the compound thread.

The price per pound of the 6's and 10's will be $7\frac{3}{8}$d., as in Example XII., while by Rule IV. the counts will be

$$\frac{6 \times 10}{6+10} = \frac{60}{16} = 3\tfrac{3}{4}\text{'s}.$$

If we now combine this $3\frac{3}{4}$'s cotton at $7\frac{3}{8}$d. per pound, with the remaining thread—*i.e.*, 15's cotton at 9d. per pound—we obtain

$$\frac{3\frac{3}{4} \times 15}{3\frac{3}{4}+15} = \frac{56\frac{1}{4}}{18\frac{3}{4}} = \frac{225}{4} \times \frac{4}{75} = 3\text{'s twist, and}$$

$$\frac{(3\frac{3}{4} \times 9)+(15 \times 7\frac{3}{8})}{3\frac{3}{4}+15} = \frac{33\frac{3}{4}+110\frac{5}{8}}{18\frac{3}{4}} = \frac{270+885}{150} = \frac{231}{30} = 7\tfrac{7}{10}\text{d.}$$

per pound, as found in Example X. In actual practice it will be found that the same method will not be most convenient for every case, and therefore the selection of the best method for any particular case must be left to the student.

Relative Weights of Yarn in a Twisted Thread.—It should be clearly understood from the foregoing examples that in the case of jute and flax counts the weights of the individual yarns in a compound thread are directly proportional to the respective counts; while in the case of lea and cotton yarns, where the twist is two-fold, the weights are inversely proportional to the individual counts. Thus, in 144lbs. of 18lbs. jute twist composed of 8lb. and 10lb. yarn there will be

Example XIV.—$\frac{144 \times 8}{18} = 64$lbs. of 8lb. yarn, and $\frac{144 \times 10}{18} = 80$lbs. of 10lb. yarn; while in

Example XV.—If 150lbs. of 6's twist cotton be com-

posed of 10's and 15's single yarns, the respective weights of these yarns will be $\frac{150 \times 15}{25} = 90$lbs. of 10's cotton and $\frac{150 \times 10}{25} = 60$lbs. of 15's cotton, or $\left.\begin{matrix} 90 \times 10 \\ 60 \times 15 \end{matrix}\right\} =$ 900 hanks of each.

The proof of above is as follows: If the total weight of a twist yarn be multiplied by its count, the product will be the total number of hanks of twist, and therefore the total number of hanks of each individual yarn. But hanks divided by the count gives the weight of that yarn. Therefore,

RULE VIII.—$\frac{\textit{Total weight} \times \textit{twisted count}}{\textit{Individual count}} = \textit{weight of}$ *individual yarn.*

Example XVI.—150lbs. of 3's twist is composed of 6's, 10's, and 15's yarn; what is the weight of each?

$$\frac{150 \times 3}{6} = 75\text{lbs. of 6's.}$$

$$\frac{150 \times 3}{10} = 45\text{lbs. of 10's.}$$

$$\frac{150 \times 3}{15} = 30\text{lbs. of 15's.}$$

$$75 + 45 + 30 = 150\text{lbs. twist.}$$

Twist Yarns Whose Individual Lengths are Different.—In jute and linen weaving it is most unusual to find twist yarns in which the take-up of one of the threads is purposely different from that of the others. In view, however, of the possible introduction of such into linen dress goods we think it necessary to include the principles involved in the calculations of these yarns. The relative lengths of the yarns may be varied at will in the twisting process, and may be determined from actual examples

by simple measurement. In general, one of the threads will be found to be practically straight and equal in length to the twisted thread, while the spiral or loop thread will be considerably longer.

Example XVII.—Suppose a spiral twist thread is composed of one thread of 10's cotton round which is twisted a thread of 2lb. flax, and that for 10ins. of twist and of the cotton thread there are 14ins. of the flax; to find the flax count and the cost per spyndle of such twist when the cotton yarn is 8d. per pound and the flax yarn 1s. 6d. per spyndle.

The relative lengths of the yarns necessary will be as 10 : 14, and assuming that a spyndle of twist is made; then $\frac{14{,}400}{840 \times 10} = 1\frac{5}{7}$lb. of 10's cotton required, and $\frac{14{,}400 \times 14}{14{,}400 \times 10} = 1\frac{2}{5}$ spyndle of 2lb. flax. Now,

$$1\tfrac{5}{7}\text{lb.} + (1\tfrac{2}{5} \times 2\text{lbs.}) = \frac{12}{7} + \frac{14}{5} = \frac{60+98}{35} = \frac{158}{35} = 4\tfrac{18}{35}\text{lbs.}$$

per spyndle, and

$$\left(\frac{12}{7} \times 8\text{d.}\right) + \left(\frac{7}{5} \times 18\text{d.}\right) = \frac{96}{7} + \frac{126}{5} = \frac{1362}{35}$$

$$= 38{\cdot}91\text{d. per spyndle.}$$

The above makes no allowance for waste in, or expense of twisting. In some cases it will be found that while different lengths of each yarn are required, the twisted length is less than that of any of the component threads. Still there should be no difficulty in solving any similar question, provided the student has a thorough knowledge of the principles underlying yarn counts. We would here impress upon all such the great desirability of mastering the principles upon which calculations are based, rather than trying to commit rules to memory.

CHAPTER III.

WARP AND WEFT SETTS AND PORTERS.

The Determination of the Sett of the Fabric.—The sett of any cloth, as far as the warp is concerned, is determined by the sett of the reed through which the warp yarn is drawn, by the number of ends contained in each split or opening of the same, and by the contraction in the width of the fabric due to weaving and finishing. As with yarn counts, there is great diversity in the methods of denoting the setts of reeds; but while in the former case there is probably some benefit to be derived from a diversity of method, in the latter there is none whatever, since in practically all calculations involving the sett of the reed it becomes necessary to at least nominally reduce the latter to threads or to splits per inch. The unification of reed bases is therefore more desirable, besides being more practicable, than the unification of yarn counts.

Since it becomes necessary in practice to reduce all reed setts to threads or splits per inch, it is obvious that the most suitable reed basis would be one whose number would indicate the threads or splits in that unit of measurement. In this respect the Huddersfield system is highly satisfactory, the number of the reed

indicating the splits per inch, while the threads per split are indicated by a small figure following the reed number. Thus: Reed 10^3 means that there are 10 splits per inch in the reed, and that there are $10 \times 3 = 30$ threads in a similar space.

Although there are only two general systems adopted in counting reeds—viz.:—

(*a*) In which the reed number indicates the number of splits within an understood unit of measurement; and

(*b*) In which the reed number indicates the multiples of a fixed number of splits (termed a beer or a porter) within an understood unit of measurement;

yet there are various modifications of each of these systems.

Under (*a*) the following, besides others, are included—

Huddersfield, in which the reed number indicates the splits on 1in.

Stockport, in which the reed number indicates the splits on 2in.

West of Scotland, in which the reed number indicates the splits on 37in.

Belfast, in which the reed number indicates the splits on 40in.

Under (*b*)—

Leeds, in which the reed number indicates the beers of 19 splits each on 9in.

Bolton, in which the reed number indicates the beers of 20 splits each on 24¼in.

Bradford, in which the reed number indicates the beers of 20 splits each on 36in.

Blackburn, in which the reed number indicates the beers of 20 splits each on 45in.

Dewsbury, in which the reed number indicates the beers of 19 splits each on 90in.

East of Scotland, in which the reed number indicates the porters of 20 splits each on 37in.

To find the splits per inch in any sett under group (*a*) the following rule is applicable :—

RULE IX.—$\dfrac{\textit{Sett of reed}}{\textit{Unit of measurement}} = \textit{splits per inch.}$

Example XVIII.—It is required to find the splits per inch in a 1,000 reed (usually written 10^{00}) West of Scotland, and an 8^{00} reed Belfast or 40in. scale. Then

$\dfrac{1{,}000 \text{ splits on } 37\text{in.}}{37\text{in.}} = 27\frac{1}{37}$ splits per inch in the former,

and $\dfrac{800 \text{ splits on } 40\text{in.}}{40\text{in.}} = 20$ splits per inch in the latter case.

To find the splits per inch in any sett under group (*b*), it is necessary to apply the following rule :—

RULE X.—$\dfrac{\textit{Sett of reed} \times \textit{splits per beer or porter}}{\textit{Unit of measurement}} =$ splits per inch.

Example XIX.—To find the splits per inch in a 10-porter and a 55-porter reed on the East of Scotland scale (this scale—*i.e.*, porters of 20 splits in 37in.—is adopted all over the East of Scotland in the jute, linen, and tweed industries).

(1.) $\dfrac{10 \text{ porter} \times 20 \text{ splits per porter on } 37\text{in.}}{37\text{in.}} =$

$5\frac{15}{37}$, or $5 \cdot 405$ splits per inch.

(2.) $\dfrac{55 \text{ porter} \times 20 \text{ splits per porter}}{37\text{in.}} =$

$29\frac{27}{37}$, or $29 \cdot 73$ splits per inch.

It is evident that since $\frac{20}{37}$ is common to all such calculations in this scale, the decimal equivalent could be found and utilised as a common factor for all cases. Thus, $\frac{20}{37} = 0 \cdot 5405$ split per inch for a 1 porter.

$\therefore$ 10 porter $\times 0 \cdot 5405 = 5 \cdot 405$ splits per inch, and 55 porter $\times 0 \cdot 5405 = 29 \cdot 7275$ splits per inch.

From splits per inch to splits in any given width is a simple step, since it is evident that splits per inch $\times$ the given width in inches will equal the splits in that width. A simple addition therefore to Rules IX. and X. gives the necessary rules for finding the splits in any reed and width.

RULE XI.—*For reeds under group (a)* :—

$$\frac{\textit{Sett of reed} \times \textit{reed width in inches}}{\textit{Unit of measurement}} = \textit{splits in the given width.}$$

Example XX.—Required the splits in 54in. of a $9^{'0}$ Belfast or 40in. scale, and in 27in. of a 12^{00} reed West of Scotland or 37in. scale.

$$(1.) \quad \frac{900 \text{ splits} \times 54\text{in.}}{40\text{in.}} = 1{,}215 \text{ splits.}$$

$$(2.) \quad \frac{1{,}200 \text{ splits} \times 27\text{in.}}{37\text{in.}} = 876 \text{ splits, nearly.}$$

RULE XII.—*For reeds under group (b)* :—

$$\frac{\textit{Sett of reed} \times \textit{splits per beer or porter} \times \textit{reed width in inches}}{\textit{Unit of measurement}}$$
$$= \textit{splits in the given width.}$$

Example XXI.—Required the splits in 43in. of an 11 porter, and in 74in. of a 50-porter reed, both on the East of Scotland scale.

$$(1.) \quad \frac{11 \text{ porter} \times 20 \text{ splits} \times 43\text{in.}}{37\text{in.}} = 256 \text{ splits, nearly.}$$

$$(2.) \quad \frac{50 \text{ porter} \times 20 \text{ splits} \times 74\text{in.}}{37\text{in.}} = 2{,}000 \text{ splits.}$$

To reduce splits per inch to any particular reed basis is a simple reversal of either Rule IX. or Rule X. If the required reed be under group (*a*), then

RULE XIII.—*Splits per inch × unit of measurement = sett of reed.*

Example XXII.—Thus, 35 splits per inch equal

$35 \times 37\text{in.} = 1{,}295$ splits or 12^{95} reed West of Scotland scale,
$35 \times 40\text{in.} = 1{,}400$,, 14^{00} ,, Belfast scale.

If the required reed is under group (*b*) :—

RULE XIV. $\dfrac{\textit{Splits per inch} \times \textit{unit of measurement}}{\textit{Splits per beer or porter}} = \textit{sett of reed.}$

Example XXIII.—Required the East of Scotland setts of 10, 20, and 30 splits per inch :—

(1.) $\dfrac{10 \text{ splits} \times 37\text{in.}}{20 \text{ splits per porter}} = 18\tfrac{1}{2}$ porter reed.

(2.) $\dfrac{20 \text{ splits} \times 37\text{in.}}{20 \text{ splits per porter}} = 37$ porter reed.

(3.) $\dfrac{30 \text{ splits} \times 37\text{in.}}{20 \text{ splits per porter}} = 55\tfrac{1}{2}$ porter reed.

Or, as indicated after Example XIX.,

$\dfrac{10 \text{ splits}}{0{\cdot}5405} = 18{\cdot}5$ porter, $\dfrac{20 \text{ splits}}{0{\cdot}5405} = 37$ porter, and

$$\frac{30 \text{ splits}}{0{\cdot}5405} = 55{\cdot}5 \text{ porter.}$$

In practice the sett of any particular reed may be determined in various ways. For reeds of a coarse sett, such as are in use in the jute trade, a metal measure or gauge termed a porter measure is used. (See Fig. 1.) The distance between the extreme points of this measure is the twentieth part of 37in.—*i.e.*, $\frac{37}{20}$in., or 1·85in. If this measure be placed upon the reed, the number of splits or openings between the two extreme points may be easily counted, and this number equals the sett of the reed or the porters of 20 splits each in 37in. This is clear, since the splits per measure × 20 measures on

37in. will equal the splits in 37in.; but this product has to be divided by 20 in order to find the porters of 20 splits each on this unit of measurement. Thus

$$\frac{10 \text{ splits per measure} \times 20 \text{ measures on 37in.}}{20 \text{ splits per porter.}} = 10.$$

For reeds of a finer sett, such as are used in the linen industry, an instrument is used which consists of a simple magnifying glass fitted over a metal plate, in the latter of which measurements of any desired kind may be cut.

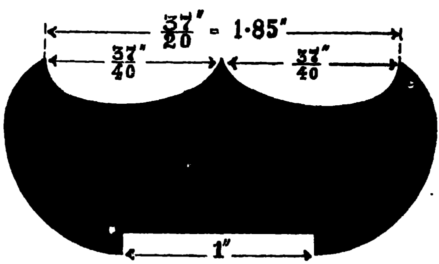


FIG. I.

An elevation of this glass is shown at Fig. 2, while a plan of the metal plate or support is illustrated in Fig. 3.

The most common measurements found are: 1in., $\frac{1}{2}$in., $\frac{1}{4}$in., $\frac{37}{40}$in., $\frac{37}{80}$in., $\frac{37}{200}$in., and $\frac{40}{200}$in.

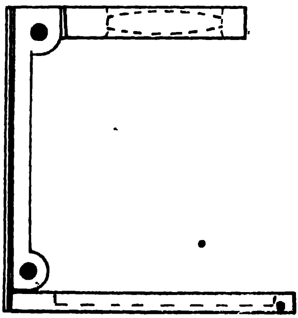
By observation the first three measurements give us immediately the splits per inch, from which the splits contained in any number of inches is easily determined. The sett of the reed in the porter or East of

Scotland scale is obtained as follows :—

Splits per	$\frac{37}{40}$	glass	$\times$	2
,,	$\frac{37}{80}$	,,	$\times$	4
,,	$\frac{37}{200}$	,,	$\times$	10

—for these measurements are respectively one-half, one-quarter, and one tenth of the full porter measure. The $\frac{37}{200}$ glass is also useful in determining the sett in the West of Scotland scale, since the splits in this measure

FIG. 2.



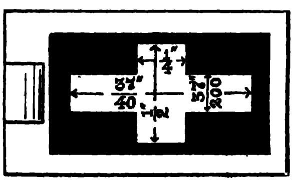


FIG. 3.

multiplied by two gives the hundreds of splits on 37in. (10 splits in measure $\times$ 2 = 20$'^{0}$). In a similar manner the $\frac{40}{200}$ glass, or $\frac{1}{5}$in., serves to determine the sett in the Belfast or 40in. scale.

It may be as well to point out at this juncture the advisability of always counting over the largest con-

venient measurement, since by so doing liability to error is diminished. Any error committed upon a small measurement is proportionately increased when the calculation is extended.

Whilst it is quite clear that the threads per inch of warp in the reed are obtained by the formula: Splits per inch × threads per split, yet in practice no invariable rule is observed as to the number of threads which shall be drawn through one split. In jute and linen weaving the number usually varies between 1 and 4 (in double warp fabrics two threads being generally considered as one), the actual number in each split being the same in any particular example, except in some special cases, such as huck towelling (huckaback) or a fabric with a crammed stripe. Due to a weave peculiarity in the former case it is sometimes necessary to draw a "two" and a "three" alternately; and in the latter case to increase the number of threads per split in the coloured portion in order to make it more effective. In certain coarse or open fabrics (say a 7-porter jute hessian, 2 threads per split always understood), where it is desired that the cloth shall be well covered—*i.e.*, the warp threads equidistant from each other—it is not an unusual practice to weave the cloth through a 14-porter reed, drawn 1 thread per split. The result is the same as far as the threads per inch are concerned, but the appearance of the cloth is considerably better than if woven in a 7-porter reed, 2 threads per split. In double warp plain fabrics—that is, where the weave is plain, but where two adjacent warp threads work together as one—it is customary to draw 2 such double threads, or 4 single threads, through each split, but in the very lowest

qualities of such bagging the practice of drawing 1 double thread per split in a reed of twice the sett or fineness is occasionally resorted to. Jute tarpaulings are similar to baggings, inasmuch as they are double warp and woven plain; they, however, are always sufficiently close in the sett to be drawn 2 double threads per split in the reed. Three-shaft twilled sackings ($\frac{2}{1}$) are also double warp, and are understood as being drawn 3 double threads—*i.e.*, 6 single threads per split. In some cases, however, they are drawn 2 double threads per split, through a finer reed than the nominal sett. Thus a 12-porter reed with 2 threads per split is equivalent to an 8-porter reed with 3 threads per split. Four-shaft twilled sackings ($\frac{3}{1}$) are always single warp and understood to have 4 threads per split, although similar variations in the method of reeding may be made for practical reasons.

In the majority of figured linen cloths 2 threads per split are understood, but in such fabrics as drills and ticking the reeding is made to suit the exigencies of the particular case. Thus, while 3 shaft drills ($\frac{2}{1}$) are usually drawn 3 threads per split, low fabrics of this type may be drawn 2 threads per split in a suitable reed. Five-shaft drills and tickings ($\frac{4}{1}$), where fine in sett, may be drawn 3, 4, or even 5 threads per split. In damask work it is a common practice to draw 3 threads through each split for cloths containing over 60 threads per inch, and 4 threads per split where about 100 threads per inch obtain. Thus, a 67½-porter damask may be woven in a 45's reed, 3 threads per split, and a 100-porter cloth in a 50's reed, 4 threads per split. Were these cloths woven in a 67½'s and a 100's reed, 2 threads per

split, a considerable increase in the number of breakages in the warp while weaving would probably be experienced, since knots in the yarn would have greater difficulty in passing the reed. The weaver would also experience greater difficulty in re-reeding those threads which did break.

The above practical considerations should not be permitted to interfere with the recognised method of designating any particular fabric. Thus the terms an 11-porter hessian, a 7-porter D.W. bagging, or an 8-porter twilled sacking, always indicate that the cloths in question no matter what they count in their present state, are the equivalents of—

1st. A hessian woven through an 11-porter reed, 2 threads per split.

2nd. A bagging woven through a 7-porter reed, 2 double threads per split.

3rd. A sacking woven through an 8-porter reed, 3 double threads per split.

In linen weaving different practices obtain in different districts, but in all cases where the sett of the warp is indicated by a reed number, it must be understood that such number refers to the sett of the loom reed through which the warp was drawn—two threads per split being assumed, except in those cases where the number of threads per split is otherwise distinctly understood. Thus a 60-porter and a 90-porter damask indicate respectively the sett of the warp of such cloths in the reed on the basis of 2 threads per split, although in the latter case the probability is that it would be woven in a 60-porter reed, 3 threads per split. Similarly, a cloth designated as a 45-porter huckaback is understood as having had

$$\frac{45 \text{ porter} \times 20 \text{ splits per porter} \times 2 \text{ threads per split}}{37\text{in.}}$$

$=48 \cdot 65$ threads per inch in the *reed*, although the warp may have been drawn 2 threads and 3 threads alternately, an average of $2\frac{1}{2}$ threads per split in a $\frac{45 \times 2}{2\frac{1}{2}} =$ 36-porter reed. In certain well-defined fabrics, such as a 3-leaf drill, 3 threads per split are understood; thus an 8^{00} 3-leaf drill, 40in. scale, would have $\frac{800 \times 3}{40\text{in.}} =$ 60 threads per inch in the reed.

Where, however, the cloth is stated as counting a given number of threads per inch, such must be taken as indicating its present actual count, and the total number of threads in any such fabric would be obtained by multiplying the given threads per inch by the given width in inches. Thus, if three cloths which measure 24in., 38in., and 54in. wide count respectively 47, 37, and 63 warp threads per inch, the total number of ends will clearly be—

In the	1st,	24in. × 47	threads	per inch	=	1,128
,,	2nd,	38in. × 37	,,	,,	=	1,406
,,	3rd,	54in. × 63	,,	,,	=	3,402

To reduce the threads per inch in the cloth to the sett of the reed through which the cloth was woven occasionally presents considerable difficulty; indeed, to do this correctly one requires, in many cases, to have had a fair amount of experience. All cloths, with very few exceptions, contract more or less in width during the weaving and the finishing processes; but, since the same number of threads is contained in any one particular fabric in its various conditions or widths, it is obvious that as the width of the cloth decreases, the number of threads per inch must inrcease. Whilst this increase is not exactly inversely proportional to the

decrease in width (a greater proportion of the contraction in width takes place at and near the selvages than in the centre of the piece), yet for calculation purposes it may be assumed to be so. Thus, a jute hessian warp which measures 43in. and counts

$$\frac{11 \text{ porter} \times 20 \text{ splits per porter} \times 2 \text{ threads per split}}{37\text{in.}}$$

$= 11 \cdot 89$ threads per inch in the reed, when woven and finished to 40in. in width will count $\frac{11 \cdot 89 \times 43\text{in.}}{40\text{in.}} =$ 12·78 threads per inch finished.

Again, a damask table cloth warp which measures $75\frac{1}{2}$in. and counts $\frac{60 \text{ porter} \times 20 \times 2}{37\text{in.}} = 64 \cdot 86$ threads per inch in the reed, will when bleached and finished to 70in. in width have $\frac{64 \cdot 86 \times 75\frac{1}{2}\text{in.}}{70\text{in.}} = 69 \cdot 95$, say 70 threads per inch. The many causes tending to produce this contraction in width have been fully discussed elsewhere, but we might briefly mention here that it is influenced in weaving chiefly by

(*a*) The weave or interlacing of the weft with the warp;

(*b*) The shotting or the threads per inch of weft;

(*c*) The size or count of the warp and of the weft yarn;

(*d*) The tension or strain imparted to the warp during the process of weaving.

In finishing, the width is modified, chiefly by the kind of finish—calendering or mangling—and by the tension imparted to the cloth in the direction of the warp during certain of the finishing processes. Due to this variety of causes, it is impossible to formulate any rule applicable to contraction in general, nor is it

safe to do so, even in any particular fabric, since experience shows that as the fabric increases in width the contraction is proportionately less. In proof of the former assertion, we may state that in the case of four different fabrics of approximately the same width which were weaving side by side, the contraction was found to vary in the weaving alone from 3 to 9 per cent. of the reed width. Notwithstanding this, practices are in daily use in certain districts which are based upon the assumption that the relation between the reed width and the loom width of the cloth is constant, or that a given width of warp in the reed will always produce the same width of cloth in the loom, irrespective of the quality or the kind of the fabric. Thus it is presumed in certain districts that 40in. of warp in the reed will always give 38in. of plain cloth, and in another (based upon approximate results in damask fabrics, but applied indifferently in that district to fabrics of all kinds and widths), that 37in. of warp in the reed will produce 36in. of cloth in the loom. It is therefore not surprising to find the fabric in many instances from 1½ to 2 per cent. too wide, incurring a corresponding waste of warp and weft; and in others that the tenter has great difficulty in keeping the cloth out to the proper width—indeed in many cases fails entirely to do so even at the expense of the quality of the cloth.

Since it is impossible to formulate a rule which would be of general application, experience must be looked to for guidance in this respect, and in each factory the figures and other data relative to each class of fabric in its various stages should be carefully collected and

tabulated for future reference and guidance. When analysing any new or unusual fabric there are means of experimentally determining, to a high degree of approximation, the allowance to be made for contraction; these will be more properly referred to under the head of analysis, and in the meantime we shall confine ourselves to stating such allowance as a percentage of the reed width. Contraction in length in weaving is practically analogous to contraction in width, but it should be observed that in finishing jute and linen fabrics the tendency is generally to increase the contraction in the width, but to decrease that in the length of the piece.

If it be stated that the contraction in the width of a certain fabric is $7\frac{1}{2}$ per cent., it is equivalent to saying that 100in. of yarn in the reed would in this case produce $(100 - 7\frac{1}{2}) = 92\frac{1}{2}$in. of cloth. But threads per inch in cloth × cloth width in inches will equal the total threads in the cloth; and if this be divided by the reed width in inches, the quotient must be the threads per inch in the reed. This quotient being divided by the threads per split (two being assumed, unless some other number is indicated), we obtain the splits per inch in the reed. From this we proceed by either Rule XIII. or Rule XIV. to find the proper sett of the reed. Arranging the above in proper form for reeds under group (*a*)—

RULE XV.—

$$\frac{\textit{Threads per inch in cloth} \times \textit{cloth width in inches} \times \textit{unit of measurement}}{\textit{Reed width in inches} \times \textit{threads per split}}$$

$$= \textit{sett of reed};$$

and for reeds under group (*b*)—

RULE XVI.—

$$\frac{\textit{Threads per inch in cloth} \times \textit{cloth width in inches} \times \textit{unit of measurement}}{\textit{Reed width in inches} \times \textit{threads per split} \times \textit{splits per beer or porter}}$$
$$= \textit{sett of reed.}$$

Example XXIV.—Given three fabrics which count respectively 13, 70, and 37 warp threads per inch, the contraction from the reed width to the present condition is 7½ per cent. in the two former cases and 5 per cent. in the latter case. Find the sett of the reed for the first two examples in the East of Scotland system, and for the last in the Belfast or 40in. scale.

Applying Rule XVI. for the first and second cases—

(1.) $$\frac{13 \times 92\tfrac{1}{2}\% \text{ cloth width} \times 37\text{in.}}{100\% \text{ reed width} \times 2 \text{ threads per split} \times 20 \text{ splits per porter}}$$
$$= 11{\cdot}12, \text{ say } 11 \text{ porter reed.}$$

(2.) $\dfrac{70 \times 92\tfrac{1}{2}\% \times 37\text{in.}}{100\% \times 2 \times 20} = 59{\cdot}89$, say 60-porter reed;

and in the third case, applying Rule XV.—

(3.) $\dfrac{37 \times 95\% \times 40}{100\% \times 2} = 703$ splits, say 7^{00} reed 40in. scale.

The sett of all jute fabrics in the way of the weft is almost invariably indicated by the number of shots or picks per inch, although in some few exceptions, where the sett is exceptionally open, say three to six picks per inch, the practice of specifying the number of picks per 3in. is becoming more general. This practice has been adopted in order to minimise the possibility of error in counting, for although the actual number of picks may be present in some parts, the average number over a large measurement may be greater or less than that visible on a single inch. The inch measure is also taken in practice for certain of the coarser linen

cloths, and while all weft setts, as in warp calculations, have to be at least nominally reduced to picks per inch, yet in practice the sett of the weft in by far the greater majority of linen fabrics is indicated by picks per glass; the recognised or standard measurement in this respect being $\frac{37}{200}$in. Whilst this measurement ($\frac{37}{200}$in.) is convenient in several respects, it is too small to lend itself to accurate results, since an error of half-a-pick on the glass is practically equal to an error of three picks per inch. To avoid this inaccuracy other measurements, such as $\frac{37}{80}$in. and $\frac{37}{40}$in., are sometimes adopted in practice. The relation between these measurements has already been indicated, and it is clear that—

Picks on the $\frac{37}{200}$ glass $\times$ 2·5 = picks on $\frac{37}{80}$ glass.
" " $\frac{37}{200}$ " $\times$ 5·0 = " $\frac{37}{40}$ "

Although these measurements are adopted for practical reasons, "picks per glass" must always be understood to indicate the number per $\frac{37}{200}$in., the actual number per inch being obtained by dividing the picks per glass by the size of the glass, thus:—

$$\frac{\text{Picks per glass}}{\frac{37}{200}} = \text{picks per inch.}$$

$$\textit{i.e.}, \text{ picks per glass} \times \frac{200}{37} = \text{picks per inch.}$$

Contracted methods are sometimes used to express the sett of the fabric; but as these have generally only a local meaning and application, and are unknown in other districts, their use should be discouraged except under circumstances which do not permit of their being misunderstood. Thus the expression that the sett of a fabric is 7/9 will in certain districts only convey the meaning that it was woven through a 7^{00} reed, 40in. scale, with 9 shots on the $\frac{37}{200}$ glass.

CHAPTER IV.

Warping Calculations.

ONE essential object of warp and weft calculations is to determine the necessary quantity of yarn to produce a definite amount of a given fabric. This quantity may be expressed in a variety of forms, but it is usually most convenient to state it in terms of the unit by which the yarn is sold. Jute yarns are sold both by weight and measure, consequently quantities of this yarn may be expressed in pounds avoirdupois or in spyndles of 14,400 yds. according to which happens to be the more suitable form. Dry spun flax yarns should be expressed in spyndles of 14,400 yds.; wet spun or lea yarns in bundles of 60,000 yds.; and cotton yarn in pounds.

In addition to finding the quantities, it is in many cases necessary to find the counts or the length of the yarn. All warp and weft calculations may ultimately be reduced to a formula which involves only three terms—viz., count of yarn, length in yards, and weight in pounds. In any yarn these three terms maintain a constant relationship, and given any two of them, the third can be determined by simple calculation.

In mill warping, which is yet extensively practised in the jute industry, and which, for the production of

some classes of striped warps, is not likely to be wholly superseded, calculations are usually limited to determining—

(*a*) The "rounds" or revolutions of the mill necessary for a given length of warp.

(*b*) The "bouts" or full traverses necessary for a given number of splits or threads.

(*c*) The position or positions at which should be placed the cutting-keel mark for the weaver's guidance. This mark represents a length in terms of "rounds" and "spokes."

The rounds in (*a*) are found by dividing the length of the warp in yards by the circumference of the mill. The length of the warp is fixed according to the requirements of the manufacturer, and is sometimes limited by the capacity of the loom beam; while the circumference of the mill usually varies between 10 yds. and 13 yds., and is subdivided into spokes by bars, which are placed parallel to the axis of the mill and about 15in. apart. Thus a 12 yd. mill may have 28 subdivisions or spokes, and so on. The necessary bouts or traverses are determined by the total number of threads or splits required, and the most suitable number of bobbins which may be placed in the bobbin bank or creel. The capacity of the latter is usually 72 bobbins, although the working limit seldom exceeds 65 bobbins. Warps from grey yarn are invariably made direct from the spinning frame bobbins. If, however, coloured threads are required in the warp, the original yarn is first reeled into hanks, bleached if necessary, dyed to the proper shades, and then rewound on to larger warping bobbins.

Orders for jute warps or chains are drawn out somewhat after the following manner: 10 chains, 256 splits, 525 yds. (37in. measure), 5 cuts, 9lb. warp, cotton selvages extra; 12 chains, 200 splits, 420 yds. (37in. measure), 4 cuts, 8½lb. double warp, twist selvage extra.

The former of the above indicates that there are to be 10 chains or warps, each containing $256 \times 2 = 512$ threads, by 525 yds. long of 37in. each ($525 \times \frac{37}{36}$in. $=$ 540 yds. approximately), and that each chain is to be keeled or marked for 5 cuts; 10 chains $\times$ 5 cuts $= 50$ cuts in all Three or four cotton threads are to be put in extra for each selvage. In the second case, which is double warp, there are 12 warps, each containing 200 splits $\times 4 = 800$ threads, by 420 yds. long of 37in. each ($420 \times \frac{37}{36}$in. $= 432$ yds. nearly), and each chain is to be keeled or marked for 4 cuts; 12 chains $\times$ 4 cuts $=$ 48 cuts in all. Three twist jute threads are to be put in extra for each selvage, indicating that the warps in question are intended for coarse fabrics—probably twilled sacking or D.W. bagging.

In warping it is seldom that an entire chain is "laid" upon the mill at one time. This is due to the fact that as layer after layer is wound upon the mill, the circumference of successive layers is gradually increasing, and therefore tending to slightly augment the actual length of the successive layers. This, if carried to any great extent, would result in tight and slack portions of the warp, and therefore an unsatisfactory beam. To avoid such a fault it is customary to take the chain off in parts, which may be either halves, thirds, quarters, or other suitable portions of the complete warp. All

parts should, of course, except in specially-indicated cases, consist of equal portions of the warp.

In the former of the above examples, each chain would be warped in two parts of 128 splits (256 threads) each ; 64 bobbins would be placed in the bank, and two bouts would be run for each part, or four bouts in all. The cotton threads would be run in with the first half bout of each part. Assuming a 12 yd. mill, then—

$\frac{540 \text{ yds.}}{12 \text{ yd. mill}} = 45$ rounds of the mill necessary, and

$\frac{45 \text{ rounds}}{5 \text{ cuts}} = 9$ rounds of mill per cut.

In the second case the chain would be warped in three parts. $\frac{200 \text{ splits}}{3 \text{ parts}} = 66\frac{2}{3}$ splits per part, or apparently 2 parts × 67 splits, and 1 part × 66 splits.

This example refers to double warp, in which two threads are to run together as one ; it is preferable to warp such chains with an even number of bobbins in the bank, or 1 part × 68 splits and 2 parts × 66 splits. For part No. 1, 68 bobbins would be banked ($\frac{68}{4} = 17$ splits) and two bouts would be run ; then for parts Nos. 2 and 3, 66 bobbins would be banked and two bouts run for each part. The twist threads could be run in with the first half bouts of parts Nos. 2 and 3.

If a 10 yd. mill, with 24 spokes or subdivisions, be used, then—

$\frac{432 \text{ yds.}}{10 \text{ yd. mill}} = 43\frac{1}{5}$ rounds, or 43 rounds, and 5 spokes necessary for the full length of the chain.

$\frac{43 \text{ rounds, } 5 \text{ spokes}}{4 \text{ cuts.}} = 10$ rounds and $19\frac{1}{4}$ spokes per cut; or

3 cuts at 10 rounds, 19 spokes, and
1 cut at 10 rounds, 20 spokes.

After warping it is necessary to weigh the chains by beam and scales, or by spring balance, and to check this weight by means of calculation. The general rule, by which the weight may be calculated, is as follows :—

RULE XVII.—

$$\frac{\textit{Splits} \times \textit{threads per split} \times \textit{length in yards} \times \textit{lb. per spyndle}}{\textit{yards per spyndle}} = \textit{weight in pounds.}$$

Applying this rule to the former of the above two examples we find :—

Example XXV.—

$$\frac{256 \times 2 \times 525 \times 37\text{in.} \times 9\text{lbs.}}{14{,}400 \times 36\text{in. per yard.}} = 172\tfrac{5}{8}\text{lb. per chain.}$$

The above, it will be observed, does not include the cotton threads in the selvages, which might add 2lbs. or 3lbs. per chain. The same rule applied to the latter example gives :—

Example XXVI.—

$$\frac{200 \text{ splits} \times 4 \text{ threads per split} \times 420 \text{ yds.} \times 37\text{in.} \times 8\tfrac{1}{2}\text{lb.}}{14{,}400 \times 36\text{in. per yd.}} = 203{\cdot}84\text{lb. per chain.}$$

which again does not include the twist threads for the selvages.

In both the above examples, 105 yds. 37in. measure, or 105 ells of 37in. each, has been used as the laid length of the cuts. This is a very convenient length from two points of view, and is regularly adopted in practice in

both chain warping and in dressing. In the latter the length is given as 108 yds. ($105 \times \frac{37}{36} = 107 \cdot 917$, practically 108 yds.) When woven, the cloth produced is approximately 100 yds. long, and this length also affords a ready means of determining the spyndles of warp in the chain from which the weight can be readily calculated.

The spyndles only for 108 yds. are found as below :—

$$\frac{256 \text{ splits} \times 2 \times 108 \text{ yds.}}{14{,}400} = \frac{256 \text{ splits} \times 3.}{200}$$

The result after cancelling shows clearly that every example of single warp—*i.e.*, of two threads per split—will work out in the same manner—*i.e.*,

$$\frac{\text{Splits} \times 3}{200}$$

—when the laid length is 108 yds. But multiplying by 3 and dividing by 200 is equivalent to adding one-half to the splits and putting in two decimal places. Thus :—

$$\frac{256 \text{ splits} \times 3}{200} = \frac{768}{200} = 3 \cdot 84 \text{ spyndles};$$

and 256 splits + 128 splits (half of 256) = 384, which, after introducing two decimal places, gives the same value as above—viz., 3·84 spyndles per cut of 108 yds. 3·84 spyndles × 5 cuts × 9lbs. per spyndle = 172·80lbs. per chain, as compared with 172·66lbs. found by the other method. (The difference is, of course, accounted for by the slight increase of the laid length—108 yds., as compared with 107·917 yds.)

In the case of double warp, where there are always four threads per split, it is obvious that the quantity will be twice that of a similar single warp example; also that in cancelling out in a similar manner the

result will always be $\frac{\text{splits} \times 3}{100}$, which is equivalent to multiplying by 3 and putting in two decimal places.

Given a case in which threads and not splits are stated, then—

$$\frac{\text{Threads} \times \text{length in yards}}{\text{Yards per spyndle}} = \text{spyndles.}$$

Assuming that the length in question is 108 yds. there is—

$$\frac{\text{Threads} \times 108}{14{,}400} = \frac{\text{threads} \times 3}{400},$$

which is clearly equivalent to deducting a quarter from the number of threads and then introducing two decimal places. Thus—

$$\frac{780 \text{ threads} \times 108 \text{ yds.}}{14{,}400} = 5 \cdot 85 \text{ spyndles,}$$

and $780 - \frac{1}{4}$ of 780,

or 780 − 195 = 585,

or 5·85 spyndles as above.

If it is preferred to treat threads instead of splits, then

100 threads × 144 yds. = 14,400 yds.

= one spyndle

—*i.e.*, 100 threads × 144 yds. = 1·00 spyndle.

Hence any number of threads 144 yds. long, with two decimal points inserted, gives the spyndles. Thus, in the previous example—

200 splits double warp = 200 × 2 × 2 = 800 threads.

800 threads 144 yds. = 8·00 spyndles.

800 „ 108 „ = 8·00 − $\frac{1}{4}$ of 8·00.

= 6·00 spyndles.

For linen weaving the process of mill warping is almost wholly superseded by the more suitable process

of beam warping. Small quantities of complicated striped warps can, however, be most economically produced by means of mill warping or by sectional warping. In these cases only a small number of bobbins is required, say sufficient for one or more repeats of the pattern; while in the case of large patterns of a symmetrical character, bobbins may only be required for half the pattern. In preparing striped patterns by means of beam warping, the simplest method, where it is practicable, is to place the white and coloured yarns on different beams, one beam for each colour, if possible; if not, two or more colours on the same beam. This can be done whenever the maximum number of coloured threads equals the capacity of one, two, or more of the beams. This method, however, has its limits, and in a great many cases it is necessary to give each beam its proper share of the pattern.

Taking a case in which a warp of 1,996 threads, 1,600 yds. long, is to be warped on 4 beams: The pattern is 20 threads blue, 4 white, 2 red, 4 white, 2 red, 4 white. It is evident that the blue yarn is the ground colour, and it is usual to so arrange the pattern that when read from selvage to selvage it will begin and end with half a ground stripe. Thus :—

Blue......	10						10	= 20
White....		4		4		4		= 12
Red......			2		2			= 4
								36 threads in pattern.

This is one of the commonest ways of representing the pattern, and it shows at a glance the character of the stripe. Another way of representing the same pattern is the following :—

Blue	10	0	0	10	=	20
White	4	4	4		=	12
Red	2	2	0		=	4

36 in pattern.

Should there be more than an equal number of repeats of the pattern in the total threads required, the common practice is to add half the surplus to each selvage, provided this surplus is not a large number. In the above case $20+4+2+4+2+4=36$ threads per repeat, and $\frac{1,996 \text{ threads}}{36 \text{ per repeat}}=55$ patterns and 16 threads over, 8 of which have to be added to each selvage. The completed pattern would therefore read :—

	Selvage.	55 repeats.	Selvage.	1996 threads.
Blue	8	10 10	8	= 1116
White		4 4 4		= 660
Red		2 2		= 220

If, however, as in the case of some large patterns, the surplus is great, then the pattern must be continued to the right and the left of the complete repeats, in all cases leaving the ground colour at each selvage. For example, the following distribution would be suitable for a pattern of 112 threads and a warp containing 2,670 threads :—

$$\frac{2,670 \text{ threads}}{112 \text{ per repeat}}=23 \text{ repeats and } 94 \text{ over.}$$

	Selvage.	23 repeats.	Selvage.	2670
Grey..	15 16	16 4 4 8 4 4 16	16 15	=1350
White.	4 8	8 4 8 2 2 2 2 8 4 8	8 4	=1128
Red ..	2 2	2 2 2 2	2 2	= 192

The above methods are only suitable where the whole of the warp goes on one loom beam. For wide ticks and similar fabrics where the width requires two or more beams, it is clear that some slight modification must be observed in order to make the pattern continuous from beam to beam.

The banking order for the various colours is determined in different ways; one method is as follows: A table may be set out in which the first vertical column shows the colours in their proper order when read from top to bottom. Should the threads in one repeat of the pattern not be a multiple of the number of beams employed, then the pattern must be repeated until the total threads in two or more repeats become a multiple of the beams employed. Succeeding columns are set apart according to the number of beams, and the threads of each colour divided on each beam in regular succession, as indicated below :—

Pattern as in Cloth.	Beam No. 1.	Beam No. 2,	Beam No. 3.	Beam No. 4.
10 Blue	3	3	2	2
4 White	1	1	1	1
2 Red			1	1
4 White	1	1	1	1
2 Red	1	1		
4 White	1	1	1	1
10 Blue	2	2	3	3

The banking order for the beams would therefore be—

	Blue	White	Red	White	Blue
Beam No. 1 ..	3	2	1	1	2
,, 2 ..	3	2	1	1	2
,, 3 ..	2	1	1	2	3
,, 4 ..	2	1	1	2	3

with an additional four threads of blue at the beginning

of each beam in order to make up the total number of threads. From the above table it will be observed that Beams Nos. 1 and 2 are exactly alike in order, as are also Beams Nos. 3 and 4, but further observation will show that the order of colouring on Beams Nos. 3 and 4 is, when read backwards, the same as the order of colouring on Nos. 1 and 2 read forwards. This similarity enables the one banking order to be used for all 4 beams, for at the dressing machine beams Nos. 1 and 2 would be placed at one end, while beams Nos. 3 and 4 would be placed at the other. In so doing the pattern in the two latter beams is reversed, or arranged backwards, thus enabling the threads from the several beams to be drawn through the leasing heddle or reed in proper order. The final arrangement would be as follows :—

Beams	Blue	White	Red	White	Red	White	Blue
No. 1	3	1	0	1	1	1	2
„ 2	3	1	0	1	1	1	2
„ 3	2	1	1	1	0	1	3
„ 4	2	1	1	1	0	1	3
	10	4	2	4	2	4	10

All symmetrical patterns may be treated in a similar manner. One-sided patterns usually require special or individual treatment which it is not possible to reduce to a well-defined rule.

In calculating the actual quantity of linen yarn used, to find the weight :—

RULE XVIII.—

$$\frac{\textit{Splits} \times \textit{threads per split} \times \textit{length in yards}}{\textit{count of yarn} \times \textit{yards per lea}} = \textit{weight in lbs.}$$

And to find the bundles :—

RULE XIX.—

$$\frac{\textit{Splits} \times \textit{threads per split} \times \textit{length in yards}}{\textit{yards per bundle } (60{,}000)} = \textit{bundles.}$$

In addition to the above general method of obtaining the quantity in bundles, there is the particular method somewhat analogous to that described for jute. Thus :—

$$1{,}000 \text{ threads} \times 60 \text{ yds.} = 60{,}000 \text{ yds.}$$
$$= 1 \text{ bundle.}$$
$$\therefore\ 1{,}000 \text{ threads} \times 60 \text{ yds.} = 1{\cdot}000 \text{ bundle.}$$

Therefore for all warps of 60 yds. length it is only necessary to put down the number of threads and mark in three decimal points, multiples or fractional parts of 60yds. being treated proportionately. Thus, a warp of 1,842 threads, 70 yds. long, contains—

1·842	bundles	for	60 yds.
0·307	,,		10 ,,
2·149	,,		70 ,,

In beam warping the following additional points require consideration :—

(*a*) The necessary number of bobbins of each colour ;

(*b*) The length of the warp ;

(*c*) The capacity of a warping bobbin ;

(*d*) The fact that when working with wet spun or lea yarns the smallest subdivision of yarn which can be conveniently wound upon a bobbin is one lea of 300 yds. ; and in flax or dry-spun yarns one heer of 600 yds.

An ordinary warping bobbin with 4in. flanges and

5in. barrel can hold approximately 1lb. of yarn. From this fact a good general guide may be taken that the bobbin will hold as many leas as the number of the yarn indicates (the capacity of the bobbin increases slightly with the counts). Thus, if dealing with 20's lea warp it may be assumed that 20 leas of 300 yds. each, or 6,000 yds. of this yarn, can be wound upon the bobbin. In the case of flax yarn it is, of course, necessary to find the equivalent lea count—*e.g.*, 2lbs. flax $= \frac{48}{2} = 24$ lea. Therefore, 24 leas, or 12 heers of 600 yds. each—*i.e.*, 7,200 yds., or half a spyndle—of 2lbs. flax yarn can be placed upon the bobbin. A much smaller bobbin is used for the higher counts.

The length of the warp mentioned in connection with the distribution of the threads on four beams was indicated as 1,600 yds. Assuming that the yarn is 30's lea, then the total number of bobbins of each colour is found as follows :—

Blue	10	$10 = 20 \times 55$ repeats	$= 1100 + 16$	$= 1116 \div 4 = 279$	bobbins
White	4 4 4	$= 12 \times 55$,,	$= 660$	$= 660 \div 4 = 165$	,,
Red	2 2	$= 4 \times 55$,,	$= 220$	$= 220 \div 4 = 55$	,,

But each bobbin has to run four beams, or 1,600 yds. $\times$ $4 = 6{,}400$ yds.

$$\therefore \frac{6{,}400 \text{ yds.}}{300 \text{ yds. per lea}} = 21\tfrac{1}{3} \text{ leas per bobbin.}$$

$21\frac{1}{3} + \frac{2}{3}$ for waste and shortage allowance $= 22$ leas of yarn which the winder is instructed to run upon each bobbin. This allowance, $\frac{\frac{2}{3} \text{ lea}}{22 \text{ lea}} \times 100 = 3$ per cent. practically, is generally sufficient to make for winders', warpers', and dressers' waste with good yarns, although with inferior yarns and those of low numbers it may be necessary to allow up to 5 or 6 per cent. As the

above yarn is 30's lea, no difficulty would be experienced in putting the requisite quantity on each bobbin.

Total quantity of colour required =

Blue $\frac{279 \text{ bobbins} \times 22 \text{ leas per bobbin} \times 300 \text{ yds. per lea}}{60{,}000 \text{ yds. per bundle.}} =$

30·69 bundles, or 30 bundles, 138 leas.

White $\frac{165 \times 22 \times 300}{60{,}000} = 18{\cdot}15$ bundles, or 18 bundles, 30 leas.

Red $\frac{55 \times 22 \times 300}{60{,}000} = 6{\cdot}05$ bundles, or 6 bundles, 10 leas.

$\therefore\ 30{\cdot}69 + 18{\cdot}15 + 6{\cdot}05 = 54{\cdot}89$, or 55 bundles in all.

The weight of this quantity, assuming for simplicity that the yarn has undergone no alteration in weight during the bleaching and dyeing processes, would be found as follows: 55 bundles × 200 leas per bundle = total number of leas. 30's lea indicates 30 leas per pound.

$$\therefore\ \frac{55 \times 200}{30} = \frac{1{,}100}{3} = 366\tfrac{2}{3}\text{lbs.}$$

Hitherto it has been assumed that the warper's beams—of which there are four—will each hold one-quarter of the total warp, or 1,996 ÷ 4 = 499 ends, each 1,600 yds. long. That the beam will do so depends entirely upon its cubical capacity and the density with which the yarn is pressed upon it. The absolute density of jute and linen fibres can easily be determined to be considerably over that of water, 1·3 being generally accepted as a close approximation to the absolute density. No yarns, however, approach this density under working conditions, even in the thread itself, and far less upon a warper's or loom beam. Investigations into numerous examples have proved that the density

in the beam condition varies from 0·45 in the case of undressed jute warps to 0·60 in dressed linen warps.

Tubes of yarn beams are usually about 5in. to 7in. diameter, while the flange diameter varies from 12in. to 16in., in the case of linen looms, and from 20in. to 26in. in the jute industry, the distance between the flanges being, of course, variable. Given the above dimensions of any beam, its cubical capacity can be readily calculated by the following formula, and therefore the quantity of yarn determined which it is capable of containing at any given density :—

Let D = diameter of beam flange in inches.

d = diameter of beam tube in inches.

l = length between flanges in inches.

c = cubical contents.

Then

$$c = D^2 \frac{\pi}{4} . l - d^2 \frac{\pi}{4} . l$$

$$= \frac{\pi}{4} . l \, (D^2 - d^2)$$

$$= \frac{\pi}{4} . l \, (D + d)(D - d)$$

If we assume that the tube of a certain beam is 6in. diameter, the flanges 12in. diameter, and the distance between the flanges 36in., then the cubical capacity of such a beam will be :—

$$\frac{3{\cdot}1416}{4} \times 36 \, (12^2 - 6^2) \, ;$$

or,

$$\frac{3{\cdot}1416}{4} \times 36 \, (12 + 6) \, (12 - 6)$$

$$= 0{\cdot}7854 \times 36 \times 18 \times 6$$

$$= 3{,}053{\cdot}6 \text{ cub. in.}$$

Now 1 cub. ft., or 1,728 cub. in., of water weigh 62½lbs.; therefore the above beam would hold

$\frac{62\frac{1}{2}\text{lbs.} \times 3{,}053}{1{,}728} = 110 \cdot 4$lbs. of a substance whose density was unity, or equal to that of water. But since the density of the warp upon the beam varies from 0·45 to 0·60, or an average of, say, 0·5, it is evident that the beam will hold only $110 \cdot 4 \times 0 \cdot 5 = 55 \cdot 2$lbs. of yarn.

Diameter of Beam Flange.	Cubic Inches per Inch Width of Beam between Flanges.	Weight in Pounds per Inch Width of Beam between Flanges, with Density=0·5.
12	84·82	1·53
13	104·46	1·89
14	125·66	2·27
15	148·44	2·68
16	172·79	3·12
17	198·71	3·59
18	226·20	4·09
19	255·26	4·62
20	285·89	5·17
21	318·09	5·75
22	351·86	6·36
23	387·20	7·00
24	424·12	7·67
25	462·60	8·36
26	502·66	9·09

In the preceding table are given the cubic inches per inch width of beam, and the weight in pounds which a beam will hold per inch of width between the flanges. This is based upon a tube of 6in. diameter, flanges from 12in. to 26in. diameter, and a density of yarn equal to 0·5. The values for other densities will be directly proportional. Thus a beam which measures 45in. between the flanges and in which the latter are 24in.

diameter, will contain approximately $7 \cdot 67 \times 45\text{in.} = 345 \cdot 15\text{lbs.}$ of warp. If the 366⅔lbs. of warp in the above warping example were required on beams whose widths between flanges were 36in., there would be $\frac{366 \cdot 66\text{lbs.}}{36\text{in.}} = 10 \cdot 18\text{lbs.}$ per inch of beam width. Hence this quantity could be placed on two beams with 20in. flanges, or on four beams with 15in. flanges. For example :—

With 20in. flanges $\frac{366 \cdot 66\text{lbs.}}{2 \text{ beams}} = 183 \cdot 33\text{lbs.}$ per beam, while capacity of beam $= 5 \cdot 17\text{lbs.} \times 36\text{in.} = 186 \cdot 12\text{lbs.}$

With 15in. flanges $\frac{366 \cdot 66\text{lbs.}}{4 \text{ beams}} = 91 \cdot 66\text{lbs.}$ per beam. and capacity of beam $= 2 \cdot 68\text{lbs.} \times 36\text{in.} = 96 \cdot 48\text{lbs.}$

Should the density be $0 \cdot 6$ instead of $0 \cdot 5$, the capacity of the beam in the latter case would be :—

$$\frac{96 \cdot 48 \times 0 \cdot 6}{0 \cdot 5} = 115 \cdot 77\text{lbs.}$$

Two further examples in warping calculations might be stated as follows : It is required to make—

1. A 36in. warp of 1,320 threads, 1,600 yds. long, from 2¼lbs. bleached flax which has lost 15 per cent. of its weight in bleaching, but gains 7½ per cent. of its bleached weight in the dressing process.

2. A 76in. warp of 6,156 threads, 2,000 yds. long, from 60's lea, less 12½ per cent. lost in creaming, plus 5 per cent. of its creamed weight during dressing.

The following particulars of the above are required :—

(*a*) The number of warper's beams, with threads and length on each beam.

(*b*) The number of bobbins required and the quantity on each bobbin.

(*c*) The total quantity of yarn required.

(*d*) The necessary number of loom warp beams, with threads, length, and weight of warp on each.

For case No. 1 four warper's beams will be most suitable. This permits of an equal number (two) being placed at each end of the dressing machine; it also gives a suitable number of threads for the warping bank or creel :—

$$\frac{1{,}320 \text{ threads}}{4 \text{ beams}} = 330 \text{ threads per beam.}$$

The warp on each beam must measure the full length, 1,600 yds., plus a dresser's allowance of, say, 1 per cent.; 1,600 + 16 = 1,616 yds. on each beam. The total number of bobbins required will be 330, provided each bobbin can hold four times the length of warp to be run on each beam—*i.e.* :—

$$1{,}616 \text{ yds.} \times 4 \text{ beams} = 6{,}464 \text{ yds. per bobbin.}$$

$$\frac{6{,}464 \text{ yds.}}{600 \text{ yds. per heer}} = 10 \cdot 77 \text{ heers per bobbin (calculated length.)}$$

10·77 heers per bobbin (calculated length).
0·23 heers for waste (approximately $2\frac{1}{4}$ per cent.)

11·00 actual quantity of heers per bobbin required.

Eleven heers of $2\frac{1}{4}$lb. flax $= 2 \cdot 25\text{lbs.} \times \frac{11}{24}$ of a spyndle $= 1 \cdot 03\text{lbs.}$, which can easily be put on the bobbin. Where the apparent quantity per bobbin exceeds the capacity of the latter, it is necessary to utilise double the number of bobbins and to put half the quantity on each. The bobbin bank then requires to be filled

twice. The total quantity of warp required is found as follows :—

$$\frac{11 \text{ heers per bobbin} \times 330 \text{ bobbins}}{24 \text{ heers per spyndle}} = 151\tfrac{1}{4} \text{ spyndles.}$$

The number of loom beams is determined by a convenient subdivision of the total length of warp and the capacity of the beam. In the present case four loom beams with 400 yds. upon each would be a satisfactory arrangement. The weight of dressed warp on each loom beam would be :—

$$\frac{1{,}320 \text{ threads} \times 400 \text{ yds.} \times 2{\cdot}25\text{lb. per spyndle} \times 85 \times 107{\cdot}5}{14{,}400 \times \underbrace{100}_{\text{\% loss in bleaching.}} \times \underbrace{100}_{\text{\% gain in dressing}}} = 75{\cdot}38\text{lb.}$$

The complete warping particulars would therefore be stated as under :—

(*a*) Four warper's beams, 330 threads, 1,616 yds. on each.

(*b*) 330 bobbins, 11 heers on each bobbin, or 11 × 600 yds. = 6,600 yds. per bobbin.

(*c*) 151¼ spyndles.

(*d*) Four loom beams, 1,320 threads, 400 yds., 75·38lbs. each.

With reference to subdivision (*b*) it must be understood that 11 heers is the quantity which the winder is instructed to allow for each bobbin; but since allowance is made in this quantity for winding and for warping waste, it is presumed that slightly less than 11 heers will be actually wound on the bobbin. It must also be remembered that after the four beams have been warped, there should still remain a small quantity of yarn on each bobbin; there should always be a suffi-

cient quantity above the calculated length to prevent them running off before the finish of the warp. These small quantities are therefore rewound on to a number of bobbins, labelled, and placed on one side, to be used when warps of the same quality and colour are again prepared. This number of bobbins must then be deducted from subdivision (*b*), and, of course, a corresponding reduction of quantity in subdivision (*c*) will be given out.

In case No. 2, where the warp is so wide that the loom beams will be in two sections, twelve warper's beams will be the most convenient, since this permits an even number of beams (six) to be used in the dressing machine for each section or half of the loom beam :—

$$\frac{6{,}156 \text{ threads}}{12 \text{ beams}} = 513 \text{ threads per beam.}$$

2,000 yds. + 1 per cent. for dresser's allowance = 2,020 yds.

$$\frac{2{,}020 \text{ yds.} \times 12 \text{ beams}}{300 \text{ yds. per lea.}} = 80\tfrac{4}{5} \text{ leas per bobbin (calculated length).}$$

$80\frac{4}{5}$ leas per bobbin (calculated length).
$1\frac{1}{5}$ lea for waste (approximately $1\frac{1}{2}$ per cent.).

82 leas, the actual quantity required per bobbin.

But since 82 leas is too much for one bobbin, it would be necessary to wind the yarn in two lots. If all the threads were cut down and replaced by the second set of bobbins immediately after the completion of half the beams, there would be :—

513 × 2 = 1,026 bobbins, each with 41 leas of yarn.

If the second set were put in the bank as the first set runs off, there would be :—

513 bobbins, each with 42 leas, or $3\frac{1}{2}$ hanks, and
513 " " 40 " $3\frac{1}{3}$ "

This latter method facilitates the winding, and causes a minimum amount of waste; but on the other hand it hinders the warping process to a considerable extent, and causes a large number of knots to be more or less in one place. Both methods are used. In either case the result is equal to :—

$$\frac{1{,}026 \text{ bobbins} \times 41 \text{ leas}}{200 \text{ leas per bundle}} = 210\tfrac{1}{3} \text{ bundles, or } 210 \text{ bundles } 66 \text{ leas.}$$

Four loom beams, or 8 halves with $\frac{6{,}156}{2} = 3{,}078$ threads, 500 yds. on each, would probably be the most convenient arrangement in this case, and the weight of dressed warp on each section would therefore be :—

$$\frac{3{,}078 \text{ threads} \times 500 \text{ yds.}}{300 \text{ yds. per lea} \times 60 \text{ leas per lb.}} \underbrace{\times \frac{87{\cdot}5}{100}}_{\substack{\text{decrease}\\ \text{in}\\ \text{creaming.}}} \underbrace{\times \frac{105}{100}}_{\substack{\text{increase}\\ \text{in}\\ \text{dressing.}}} = 78{\cdot}55 \text{lb.}$$

The complete particulars for case No. 2 are therefore:—

(*a*) Twelve warper's beams, 513 threads, 2,020 yds. on each.

(*b*) 1,026 bobbins, 41 leas on each, or 41 × 300 yds. = 12,300 yds. per bobbin.

(*c*) 210⅓ bundles.

(*d*) Eight half loom beams, 3,078 threads, 500 yds., 78·55lbs. each.

CHAPTER V.

WARP AND WEFT CALCULATIONS.

IT has already been stated that the three chief terms involved in all yarn calculations—viz., the count of the yarn, the length in yards, and the weight in pounds—maintain a constant relationship; and given any two of them, the third can be easily determined. Of these terms probably the one which is most usually unknown in practice is the last—*i.e.*, the weight of the yarn in pounds. But in the last two examples, XXV. and XXVI., it has been shown in particular cases how this term may be found for flax (or jute) and for linen (or cotton) yarns. Thus, in the former case, for any grey yarn the case may be generally stated by

RULE XX.—

$$\frac{\textit{The length in yards} \times \textit{count (pounds per spyndle)}}{\textit{Yards per spyndle}} = \textit{weight in pounds}; \text{ or}$$

$$\textit{The length in yards} \times \textit{count (pounds per spyndle)} = \textit{yards per spyndle} \times \textit{weight in pounds}.$$

If, therefore, the count and the weight of any jute or flax yarn be given, it is obvious that the length in yards can be found by the following rule:—

RULE XXI.—

$$\frac{\textit{Yards per spyndle} \times \textit{weight in pounds}}{\textit{Count (pounds per spyndle)}} = \textit{the length in yards.}$$

Also that given the length in yards and the weight in pounds, the following rule gives the count or pounds per spyndle :—

RULE XXII.—

$$\frac{\textit{Yards per spyndle} \times \textit{weight in pounds}}{\textit{The length in yards}} = \textit{the count or pounds per spyndle.}$$

If the length in yards is not expressed directly, it must be calculated from the facts given. Thus :—

Example XXVII.—How many yards of a warp of 1,152 threads can be made from 42½lbs. of 3lb. flax yarn which has been reduced 15 per cent. in weight by bleaching ? Assume a loss of 4 per cent. in the various preparatory processes of winding, warping, and dressing.

Since the yarn in its present condition is only 100 − 15 = 85 per cent. of its original, or grey, weight, clearly that weight must have been $\frac{42\cdot5\text{lbs.} \times 100}{85} = 50\text{lbs.}$; but if a loss of 4 per cent. is incurred in the preparatory processes, the actual quantity of yarn which enters the warp will be equivalent to $\frac{50\text{lbs.} \times 96}{100} = 48\text{lbs.}$ of grey warp. But 48lbs. ÷ 3lbs. per spindle = 16 spyndles, or 16 × 14,400 yds. = 230,400 yds. Now, in the warp there are to be 1,152 threads, therefore,

$$\frac{230,400 \text{ yds.}}{1,152 \text{ threads}} = 200 \text{ yds. of warp.}$$

The above working may be expressed in a single calculation based upon Rule XXI. Thus :—

$$\frac{42{\cdot}5\text{lb.} \times \overbrace{100}^{} \times \overbrace{96}^{} \times 14{,}400 \text{ yds. per spyndle}}{1{,}152\text{thds.} \times \underbrace{85}_{\substack{\%\text{ loss}\\ \text{in}\\ \text{bleaching.}}} \times \underbrace{100}_{\substack{\%\\ \text{waste.}}} \times 3\text{lb. per spyndle}} = 200 \text{ yds.}$$

Example XXVIII.—It may be necessary to determine the count of the jute yarn composing a warp of 880 threads, 540 yds. long, and weighing 346½lbs., to which 5 per cent. of size has been added in the dressing process. Since the weight of the warp has been increased by 5 per cent. of its original weight, or in effect has become 105 per cent. of that weight, obviously the grey weight will be found as follows :—

$$\frac{346\tfrac{1}{2}\text{lbs.} \times 100}{105} = 330\text{lbs.}$$

But 880 threads × 540 yds = 475,200 yds., the total length of the warp; and since 330lbs. ÷ 475,200 yds. would give the weight of 1 yd., this quotient multiplied by 14,400 yds. gives the weight of one spyndle = 10lbs. Or arranged according to Rule XXII. :—

$$\frac{346{\cdot}5\text{lb.} \times 100 \times 14{,}400 \text{ yds. per spyndle}}{105 \times 880 \text{ threads} \times 540 \text{ yds.}} = 10\text{lbs. per spyndle.}$$

Whilst the foregoing rules are applicable to flax and jute yarns, other formulæ are necessary for lea and cotton yarns, and for all those yarns whose counts are inversely proportional to their cross-sectional areas or weights. On page 13 it is shown that the count may be determined when the length and the weight of the yarn are given, and in Example XXVI. how the weight may be calculated when the length and the count are known. From these it can be deduced that the length in yards × unit of weight = weight of yarn × unit of length × count, and therefore that—

RULE XXIII.—

$$\frac{\textit{The length in yards} \times \textit{unit of weight}}{\textit{Unit of length} \times \textit{count}} = \textit{weight of yarn in pounds.}$$

Or that

RULE XXIV.—

$$\frac{\textit{The length in yards} \times \textit{unit of weight}}{\textit{The weight of yarn} \times \textit{unit of length}} = \textit{the count.}$$

And further that

RULE XXV.—

$$\frac{\textit{The unit of length} \times \textit{count} \times \textit{weight in pounds}}{\textit{The unit of weight}} = \textit{the length in yards.}$$

In any single example it is necessary to express the weights in similar terms. Thus, while the unit of weight is generally 1lb., it may be necessary to express this weight in grains, ounces, or other subdivisions, according to the manner in which the weight of the yarn is stated.

Example XXIX.—Required the length in yards of a cotton warp containing 1,600 threads of 8's cotton, and weighing 99lbs. The yarn lost 10 per cent. weight in bleaching, but increased by 10 per cent. of its bleached weight in dressing. It must be distinctly remembered that the increase of 10 per cent. on the bleached weight is not equivalent to the decrease of 10 per cent. from the grey; consequently, the increase in dressing does not balance the loss in bleaching. Each percentage must therefore be treated separately in the calculation.

If the dressed weight is 99lbs., or 110 per cent. of the bleached weight, then the latter must have been $\frac{99\text{lbs.} \times 100}{110} = 90\text{lbs.}$ But as this weight is only 90

per cent. of the grey weight, the latter must have been $\frac{90\text{lbs.} \times 100}{90} = 100\text{lbs.}$ Now in 100lbs. of 8's cotton there are $100 \times 8 \times 840 = 672{,}000$ yds., which divided by 1,600 threads gives 420 yds. per thread. Or, applying Rule XXV., there are

$$\frac{840 \text{ yds.} \times 8\text{'s} \times 99\text{lbs.} \times 100 \times 100}{1\text{lb.} \times 1{,}600 \text{ threads} \times \underbrace{110}_{\substack{\% \\ \text{dressing.}}} \times \underbrace{90}_{\substack{\% \\ \text{bleaching.}}}} = 420 \text{ yds.}$$

Example XXX.—A beam of creamed and dressed linen warp weighs 98lbs. and contains 3,200 threads, each 500 yds. long. The yarn lost $12\frac{1}{2}$ per cent. weight in creaming, but increased by 5 per cent. of its creamed weight in dressing. Find the count of the yarn.

There are several ways by which the above may be reasoned out. First, the grey weight of the yarn may be found, and then Rule XXIV. applied. Thus :—

$\frac{98\text{lbs.} \times 100 \times 100}{105 \times 87 \cdot 5} = 106\frac{2}{3}\text{lbs.}$ grey weight of yarn.

Then

$$\frac{3{,}200 \text{ threads} \times 500 \text{ yds.} \times 1\text{lb.}}{300 \text{ yds. per lea} \times 106\frac{2}{3}\text{lbs.}} = 50\text{'s lea.}$$

Second, the count of the yarn may be found in the dressed condition by Rule XXIV., and then increased and decreased to the creamed and the grey condition respectively, according to the respective percentages of increase and decrease in the weight of the yarn. Thus :—

$\frac{3{,}200 \text{ threads} \times 500 \text{ yds.}}{300 \text{ yds. per lea} \times 98\text{lbs.}} = 54\frac{62}{147}$ lea in the dressed condition.

But since the yarn is lighter in the creamed state as compared with the dressed state in the proportion 105 to 100, the count must be higher in the proportion 100 to 105; therefore the count in the creamed state is :—

$$54\tfrac{62}{147} \times \frac{105}{100}, \text{ or } \frac{8{,}000}{147} \times \frac{105}{100} = 57\tfrac{1}{7} \text{ lea.}$$

In the grey condition, however, the yarn is heavier than in the creamed state in the proportion 87·5 to 100; hence the count in the grey condition will be less in the proportion 100 to 87·5. Or

$$57\tfrac{1}{7} \times \frac{87\cdot5}{100}, \text{ or } \frac{400}{7} \times \frac{87\cdot5}{100} = 50\text{'s lea grey.}$$

The above working may be stated more concisely as under :—

$$\frac{3{,}200 \times 500 \times 105 \times 87\cdot5}{300 \times 98 \times 100 \times 100} = 50\text{'s lea grey.}$$

Weft Calculations.—To determine the total length of weft in any given fabric only two facts are necessary—viz., the total number of picks or shots in the cloth, and the length of each pick.

The first of these may be stated in a variety of ways—*e.g.*, picks per inch, picks per ¼in., picks per glass, &c.; but in all cases where a fractional measure is given, the first step is to reduce to picks per inch. Since the cloth length is usually given in yards, it is then necessary to multiply the picks per inch by 36 in order to obtain the picks per yard, and again to multiply by the length of the piece in yards in order to find the total picks. Having found the total picks, further multiplication by the length of each pick will give the total length of the weft in terms of the unit in which the length of each pick

was taken. But since this latter item is, like the width of the fabric, generally expressed in inches, the result will be obtained in inches, and division by 36 would be necessary to have the length expressed in yards. Multiplication and division by 36 cancel each other, however, and it is usual to express this formula as follows: Picks per inch × cloth length in yards × length of each pick in inches = length of weft in yards. (In some cases the length of the piece is given in yards of 37in. each, and in such cases it is, of course, necessary to multiply by 37 and divide by 36 to insure the length of the weft being expressed in imperial yards.)

RULE XXVI.—Picks per inch × reed width in inches (including selvages) × cloth length in yards = total length of weft in yards.

Further calculation will, of course, be necessary, according as it is desired to express the result in units of length or of weight.

Example XXXI.—Find the spyndles of weft in 105yds. of 40in. hessian, counting 13 shots per inch, and measuring 43in. in the reed.

$$\frac{13 \text{ picks per inch} \times 43\text{in.} \times 105 \text{ yds.}}{14{,}400 \text{ yds. per spyndle.}} = 4\cdot 08 \text{ spyndles.}$$

Example XXXII.—What weight of weft is there in 90 yds. of 24in, huck towelling, weft 2½lb. flax, less 15 per cent. loss in bleaching, 8 shots per glass, contraction from reed to finished width 10 per cent.?

$$\overbrace{\left(\frac{8 \text{ shots per glass} \times 200}{37}\right)}^{\text{Shots per inch.}} \times \overbrace{\left(\frac{24\text{in.} \times 100}{\underset{\text{\% contraction.}}{90}}\right)}^{\text{Reed width.}} \times$$

$$\frac{90 \text{ yds.}}{14{,}000} \times \left(\frac{2\cdot 5\text{lb.} \times 85}{\underset{\text{\% loss in bleaching.}}{100}}\right) = \frac{1{,}700}{111} = 15\cdot 32\text{lbs.}$$

Example XXXIII.—Calculate the quantity in bundles and the weight in pounds of weft necessary for 500 yds., 37in. measure, of 38in. linen, counting 12 shots to the glass. Weft 55's lea. Contraction from reed to loom width 5 per cent.

$$\underset{\text{Shots per inch.}}{\left(\frac{12 \times 200}{37}\right)} \times \underset{\text{Reed width.}}{\left(\frac{38 \times 100}{95}\right)} \times \left(\frac{500 \times 37}{36}\right) \times$$

$$\frac{1}{60{,}000 \text{ yds. per bundle}} = \frac{200}{9} = 22{\cdot}22 \text{ bundles of weft.}$$

Then

$$\frac{22{\cdot}22 \text{ bundles} \times 200 \text{ leas per bundle}}{55 \text{ leas per pound}} = 80{\cdot}8\text{lbs. of weft.}$$

Example XXXIV.—Find the weight of 16's bleached cotton weft in 10 pieces, 80 yds. each, 70in. union damask, 13 shots per glass, contraction from reed to finished width 8 per cent. The yarn lost 8 per cent. weight in bleaching.

$$\underset{\text{Shots per inch.}}{\left(\frac{13 \times 200}{37}\right)} \times \underset{\text{Reed width.}}{\left(\frac{70 \times 100}{92}\right)} \times$$

$$\left(\frac{80 \text{ yds.} \times 10 \text{ pieces}}{840 \text{ yds. per hank} \times 16 \text{ hanks per pound}}\right) \times \underset{\text{\% loss in bleaching.}}{\frac{92}{100}} =$$

$$292{\cdot}79\text{lbs.}$$

In weft calculations no allowance should be made for contraction from warp length to cloth length, but it is well to observe that the picks per inch, at any stage of the process from loom to finished state, must be multiplied by the length of the cloth in that stage, and in all cases by the reed width.

CHAPTER VI.

Calculations for Jute Fabrics.

To illustrate the method of determining the yarns necessary for a given fabric, a few examples representative of the general types of jute fabrics will be worked out. The particulars given are not necessarily those of fabrics in actual work, although this may happen, the object being to illustrate the principles involved in such calculations rather than to record facts concerning any particular cloth.

Hessian.—This is probably the most largely manufactured of all jute fabrics. It is a plain cloth, is made in practically all widths, and is used for an enormous variety of purposes. The standard make upon which prices are usually based is: 11 porter, 40in. wide, 10½ozs. per yard, 13 shots per inch, chested finish. Lighter and heavier makes are made with suitable variations of the setts and yarns, the usual extremes of weight being about 6ozs. and 14ozs. per yard, 40in. wide. In many cases no variation is made in the sett of the fabric nor in the count of the warp, for an increase in weight above 10½ozs., this being obtained by simply changing the weft; below 10½ozs. per yard it is usual to alter the sett as well as the yarns.

Example XXXV.—11 porter, 40in. hessian, $10\frac{1}{2}$ozs. per yard, 13 shots per inch finished.

Warp, $8\frac{1}{2}$lbs. per spyndle = 9lbs. per spyndle dressed. Length of warp = 108 yds. Finished length = 105 yds. Reed width = $43\frac{1}{2}$in.

Warp.

$$\frac{11 \text{ porter} \times 20 \times 43\frac{1}{2}\text{in.}}{37\text{in.}} = 258 \text{ splits.}$$

258 splits − 4 splits cotton = 254 splits jute.

$$\frac{258 \text{ splits} \times 2 \text{ threads per split} \times 108 \text{ yds.}}{14{,}400 \text{ yds. per spyndle.}} = 3\cdot87 \text{ spyndles.}$$

3·87 spyndles × 9lbs. per spyndle = 34·83lbs. warp.

In the above the assumption is made that the cotton yarn in the selvages will weigh the same as an equal quantity of jute threads.

$$\frac{105 \text{ yds.} \times 10\frac{1}{2}\text{ozs. per yard}}{16\text{ozs. per pound.}} = 68\cdot91\text{lbs. per cut of 105 yds.}$$

68·91lbs. − 34·83lbs. of warp = 34·08lbs. of weft necessary.

Weft.

$$\frac{13 \text{ shots} \times 43\frac{1}{2}\text{in.} \times 105 \text{ yds.}}{14{,}400 \text{ yds. per spyndle}} = 4\cdot12 \text{ spyndles of weft per cut.}$$

$$\frac{34\cdot08\text{lbs. of weft}}{4\cdot12 \text{ spyndles}} = 8\cdot27\text{lbs. per spyndle.}$$ But to allow for waste $8\frac{1}{2}$lbs. per spyndle weft will be used.

4·12 spyndles × $8\frac{1}{2}$lbs. = 35·02lbs. weft.

34·83lbs. warp + 35·02lbs. weft = 69·85lbs. in all.

69·85lbs. − 68·91lbs. = 0·94lbs. for waste, or about $1\frac{1}{2}$ per cent.

This waste allowance covers only loss in weight due to weaving, and does not include the waste in quantity

by weaver, winder, or dresser, for which it is necessary to make allowance when estimating the cost.

Mangled Hessian.—This is a fabric similar to the ordinary hessian, but differently finished. In some cases, exactly the same quality of yarn is used, whilst in other makes superior yarns are employed. When the length of the cloth is compared with that of the ordinary hessian made from the same warp, a slightly shorter piece is obtained; this is due to the above-mentioned difference in finishing, and for the same reason a smaller allowance for contraction in width is sufficient for the mangled hessian.

Example XXXVI.—11 porter, 40in., $10\frac{1}{2}$ozs., mangled hessian, $14\frac{1}{2}$ shots per inch finished. Warp, 8lbs. per spyndle $= 8\frac{1}{2}$lbs. dressed. Warp length $= 108$ yds. Finished length $= 103$ yds. Reed width $= 42\frac{1}{2}$in.

Warp.

$$\frac{\overset{\text{Splits.}}{\left(\dfrac{11 \times 20 \times 42\frac{1}{2}}{37}\right)} \times \overset{\text{Threads per split.}}{2} \times 108 \text{ yds.} \times \overset{\text{Count.}}{8\frac{1}{2}\text{lbs.}}}{\times\ 14{,}400 \text{ yds. per spyndle}} = 32\cdot22\text{lbs. warp.}$$

$$\frac{103 \text{ yds.} \times 10\frac{1}{2}\text{ozs.}}{16\text{ozs. per pound}} = 67\cdot59\text{lbs. per cut of 103 yds.}$$

$67\cdot59$lbs. $- 32\cdot22$lbs. $= 35\cdot37$lbs. of weft required.

Weft.

$$\frac{14\frac{1}{2} \text{ shots} \times 42\frac{1}{2}\text{in.} \times 103 \text{ yds.}}{14{,}400\text{yds. per spyndle}} = 4\cdot41 \text{ spyndles of weft in cut.}$$

$$\frac{35\cdot37\text{lbs. of weft}}{4\cdot41 \text{ spyndles}} = 8\cdot02\text{lbs. per spyndle, say } 8\tfrac{1}{4}\text{lbs. weft to allow for waste.}$$

$4\cdot41$ spyndles $\times 8\frac{1}{4}$lbs. $= 36\cdot38$lbs.

$32\cdot22$lbs. $+ 36\cdot38$lbs. $= 68\cdot60$lbs.

68·60lbs. − 67·59lbs. = 1·01lbs. for waste allowance.

Tarpauling.—This is a double warp plain fabric, and its weight is often based upon a width of 45in., although it is also a common practice to state the weight per yard for the particular width required. The allowance necessary for any width, and also the finished length obtained from a given length of warp, will vary in this, as in all other cases, with the make of the fabric and the style of finish; such particulars can only be determined by experience.

Example XXXVII.—10 porter, 45in., 20ozs. per yard, D.W. tarpauling, 12½ shots per inch finished. Warp 9lbs. per spyndle dressed. Laid length = 108 yds. Finished length = 103 yds. Reed width = 48in.

Warp.

$$\frac{\left(\frac{10 \text{ porter} \times 20 \times 48}{37}\right) \underset{\text{Splits.}}{} \times \underset{\text{Threads per split.}}{4} \times \underset{\text{Yards.}}{108} \times \underset{\text{Count.}}{9\text{lbs.}}}{14{,}400 \text{ yds. per spyndle}} = 70 \cdot 05\text{lbs. warp.}$$

Weft.

$$\frac{12\tfrac{1}{2} \text{ shots} \times 48\text{in.} \times 103 \text{ yds.}}{14{,}400 \text{ yds. per spyndle}} = 4 \cdot 29 \text{ spyndles weft.}$$

$$\frac{103 \text{ yds.} \times 20\text{ozs. per yard}}{16\text{ozs. per pound}} = 128 \cdot 75\text{lbs. per cut.}$$

128·75lbs. − 70·05lbs. of warp = 58·70lbs. of weft.

$$\frac{58 \cdot 70\text{lbs. of weft}}{4 \cdot 29 \text{ spyndles}} = 13 \cdot 68\text{lbs., say 14lbs. per spyndle weft.}$$

4·29 spyndles × 14lbs. = 60·06lbs.

70·05lbs. + 60·06lbs. = 130·11lbs. in all.

130·11lbs. − 128·75lbs. = 1·36lbs. waste—about 1 per cent.

D.W. Bagging.—This also is a double warp plain fabric, but of a different class from tarpaulings, the sett being usually much coarser, and the count of the weft heavier than in the latter type. The standard width is generally taken as 44in.

Example XXXVIII.—7 porter, 44in., 24ozs., D.W. bagging, 9 shots per inch finished. Warp $8\frac{1}{4}$lbs. per spyndle undressed. Laid length = 108 yds. Finished length = 102 yds. Reed width = $46\frac{1}{2}$in.

Warp.

$$\frac{\left(\dfrac{\overset{\text{Splits.}}{7 \text{ porter} \times 20} \times 46\frac{1}{2}}{37}\right) \times \overset{\text{Threads per split.}}{4} \times 108 \text{ yds.} \times 8\frac{1}{4}\text{lbs.}}{\times 14{,}400 \text{ yds.}} =$$

43·54lbs. warp.

Weft.

$$\frac{9 \text{ shots} \times 46\frac{1}{2}\text{in.} \times 102 \text{ yds.}}{14{,}400 \text{ yds. per spyndle}} = 2 \cdot 96 \text{ spyndles weft.}$$

$$\frac{102 \text{ yds.} \times 24\text{ozs.}}{16\text{ozs. per pound}} = 153\text{lbs. per cut.}$$

153lbs. − 43·54lbs. warp = 109·46lbs. weft necessary.

$$\frac{109 \cdot 46\text{lbs.}}{2 \cdot 96 \text{ spyndles}} = 36 \cdot 98\text{lbs. per spyndle, say 38lbs. weft.}$$

2·96 × 38lbs. per spyndle = 112·48lbs. weft.

43·54lbs. warp + 112·48lbs. weft = 156·02lbs. in all.

156·02lbs. − 153lbs. = 3·02lbs. waste allowance—about 2 per cent.

Twilled Sacking.—This is a double warp fabric, woven with the three-leaf twill $\frac{2}{1}$ with three double or six single threads of warp per split in the reed. The commonly accepted standard width is 27in., but it is a general practice, when other widths are required, to specify the weight per yard for such widths. In some

cases the weight may also be indicated upon the basis of some other suitable width. Thus the expressions, 8 porter, 27in., 16ozs.; 12 porter, 29in., 24ozs.; and 7 porter, 60in., 16ozs.—36in., are quite common.

Example XXXIX.—10 porter, 28in., 20ozs., twilled sacking, 11 shots per inch finished. Warp 9lbs. per spyndle dressed. Laid length = 108 yds. Finished length = 102 yds. Reed width = 29½in.

Warp.

$$\frac{\left(\frac{\overset{\text{Splits.}}{10 \text{ porter} \times 20} \times 29\frac{1}{2}\text{in.}}{37}\right) \times \overset{\text{Threads per split.}}{6} \times \overset{\text{Yards.}}{108} \times \overset{\text{Count.}}{9\text{lbs.}}}{14{,}400 \text{ yds. per spyndle.}} = 64\cdot58\text{lbs. warp.}$$

Weft.

$$\frac{11 \text{ shots} \times 29\frac{1}{2}\text{in.} \times 102 \text{ yds.}}{14{,}400 \text{ yds. per spyndle.}} = 2\cdot30 \text{ spyndles of weft.}$$

$$\frac{102 \text{ yds.} \times 20\text{ozs. per yard}}{16\text{ozs. per pound}} = 127\cdot5\text{lbs. per cut.}$$

$127\cdot5\text{lbs.} - 64\cdot58\text{lbs.} = 62\cdot92\text{lbs.}$ of weft required.

$$\frac{62\cdot92\text{lbs.}}{2\cdot30 \text{ spyndles}} = 27\cdot36\text{lbs., say } 28\text{lbs. per spyndle.}$$

$2\cdot30$ spyndles $\times$ 28lbs. $= 64\cdot40$lbs. of weft.

$64\cdot58\text{lbs.} + 64\cdot40\text{lbs.} = 128\cdot98\text{lbs.}$ in all.

$128\cdot98\text{lbs.} - 127\cdot5\text{lbs.} = 1\cdot48\text{lbs.}$ waste—about 1¼ per cent.

Whilst the foregoing examples are representative of the general types of jute cloths, a considerable quantity of the fibre is woven into fabrics of a more or less elaborate character, the chief general purpose of which is floor covering. Plain and twilled carpeting or matting, imitation Scotch or Kidder, Brussels and Wilton carpeting and tapestry, form the chief varieties.

The latter class is also imitated by a peculiar two-shaft reversible fabric termed "Imitation tapestry" or "Brusselette." For the production of this cloth two warp beams are necessary, one carrying a so-called ground or binding warp, and the other what is termed the pile warp. The ground warp is all drawn through the heddles of one shaft, and the pile warp through those of other two shafts, the latter being then tied together and wrought as one, and the whole actuated as in a plain weave by an ordinary two-shaft shedding tappet. Three threads (one thread ground, two threads pile) are drawn through each split of the reed, which is

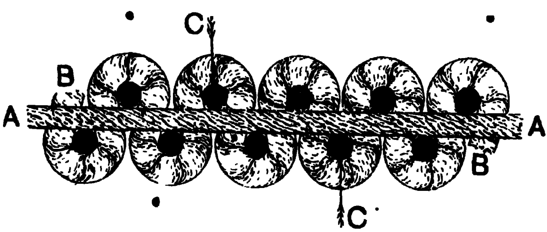


FIG. 4.

usually 10, 11, or 12 porter. A weft section of this cloth is shown in Fig. 4 from which it is evident that the take-up or contraction of the pile warp B will be considerably greater than that of the ground warp A; hence the necessity for the two warp beams. In order to induce this difference in contraction the ground warp A is held at very high tension, whilst very little tension is applied to the pile warp B. This tension is so small that the weft, in its forward movement by the reed, is enabled to draw forward the pile warp from its beam, and along with these threads to take up a position alternately on each side of the ground warp as indicated.

It will be understood that the ground warp A should be of superior quality, two-ply 5lb. yarn being sometimes used, although 11lb. and 12lb. single yarn are often employed. A soft twisted two-ply 8lb. or two-ply 9lb. thread appears to give the most satisfactory results for the pile warp. The cloth length obtainable from a given length of pile warp may, within certain limits, be varied at will by suitable alterations of the shotting, and of the pace or tension of the pile warp beam. There is practically no contraction of the ground warp, but an allowance of, say, 1 to 2 per cent. may be made in the calculation.

Example XL.—12 porter, 36in. imitation tapestry, 14 shots per inch; ground warp, 11lbs. per spyndle, dyed and starched; pile warp, two-ply 9lb. dyed, or dyed and printed; weft, 11lbs. per spyndle dyed. It is assumed that 75 yds. of cloth require 140 yds. of pile warp and 76 yds. of ground warp. Reed width, 36½in. With these goods there is practically no contraction in width.

$$\text{Splits}: \frac{12 \text{ porter} \times 20 \times 36\frac{1}{2}}{37} = 237 \text{ splits in reed.}$$

$237 - 2$ splits (cotton selvages) $= 235$ splits jute yarn.

$235 \times 2 = 470$ threads of 2-ply 9lb. jute pile warp.

$235 \times 1 = 235$ threads of 11lb. jute ground warp.

$$\frac{470 \text{ threads} \times 140 \text{ yds.} \times 2/9\text{lbs. (18lbs.)}}{14{,}400 \text{ yds. per spyndle}} = 82 \cdot 25\text{lbs. pile warp.}$$

$$\frac{235 \text{ threads} \times 76 \text{ yds.} \times 11\text{lbs.}}{14{,}400 \text{ yds. per spyndle}} = 13 \cdot 64\text{lbs. ground warp.}$$

$$\frac{14 \text{ shots} \times 36\frac{1}{2}\text{in.} \times 75 \text{ yds.} \times 11\text{lbs.}}{14{,}400 \text{ yds. per spyndle}} = 29 \cdot 28\text{lbs. weft.}$$

$$\frac{4 \text{ threads} \times 76 \text{ yds.}}{\underset{\substack{\text{Yards}\\ \text{per hank.}}}{840} \times \underset{3/12}{4\text{'s}}} = 0 \cdot 09\text{lbs. cotton.}$$

Total weight $= 125 \cdot 26$lbs.

$$\frac{125 \cdot 26 \times 92 \cdot 5}{\underset{\substack{\%\text{ loss of}\\ \text{weight in dyeing.}}}{100}} = 115 \cdot 86, \text{ say } 116\text{lbs. per cut of } 75 \text{ yds.}$$

$$\frac{116\text{lbs.} \times 16\text{ozs. per lb.}}{75 \text{ yds. cloth}} = 24 \cdot 75\text{ozs. per yard.}$$

Specimen calculations of other varieties of fancy jute fabrics might be given, but no further principle would be illustrated, since in all cases the methods of procedure are practically alike. First, the reed width necessary to produce the desired finished width of cloth has to be fixed; and, second, an approximation made as to the finished length which may be obtained from a known length of warp. Having fixed these particulars upon a basis of former experience, a provisional calculation may be made. Should an order be obtained this estimate should be checked, if possible, by the making of a sample beam. All particulars could then be collected from the finished fabric, and any obvious alterations effected before the whole order is run.

CHAPTER VII.

Calculations for Linen Fabrics.

Calculations in linen fabrics, as, indeed, in all textiles, are somewhat analogous to those in jute; but in the linen industry a large variety of fabrics obtains, while the cloths differ greatly from the points of view of purpose and quality. Under plain weave alone are found such cloths as canvas or sailcloth, artist's canvas, duck and dowlas, hollands, cambric, lawn and other dress linen, apron linen, pillow linen and sheeting, glass, tea and other household cloths, crash towelling, paddings, screw cloths, strainers, scrims, dusters, blue and checked linens, embroidered and hem-stitched linens for furniture decoration, toilet requisites, &c. In tappet weaves, other than plain, there are drills, sheetings, tickings, mattresses, dusters, towellings, rubbers, huckabacks, &c.; while in dobby and jacquard productions there is a wide range of dice, diaper, and damask fabrics intended chiefly for table decoration, although a limited portion is utilised for dress goods, and for stair and floor coverings. In addition to the above it must be remembered that in each class there is usually a wide range of qualities due to variation of setts and of the

kind, quality, colour, and counts of the yarns employed. We shall therefore restrict ourselves to a few examples which will be sufficiently representative and explanatory of the principles involved.

Example XLI.—24 porter double warp flax canvas, 24in. wide, 18ozs. per yard, 19½ shots per inch, reed width, 25in.; warp length, 50 yds.; cloth length, 40 yds.; warp, 6lbs. per spyndle. Both warp and weft lose 7½ per cent. in the boiling process.

Warp.

$$\underset{\text{Splits per inch.}}{\left(\frac{24 \text{ porter} \times 20}{37}\right)} \times \underset{\text{Reed width.}}{25\text{in.}} \times 4 \text{ threads per split} = 1{,}297,$$

say 1,300 threads.

$$\frac{1{,}300 \text{ threads} \times 50 \text{ yds.} \times 6\text{lbs. per spyndle}}{14{,}400 \text{ yds. per spyndle}} \times \underset{\substack{\%\text{ waste in}\\ \text{boiling.}}}{\left(\frac{92 \cdot 5}{100}\right)} =$$

25·05lbs. warp.

Weft.

$$\frac{19\tfrac{1}{2} \text{ shots} \times 25\text{in.} \times 40 \text{ yds.}}{14{,}400 \text{ yds.}} = 1 \cdot 35 \text{ spyndle weft.}$$

$$\frac{40 \text{ yds.} \times 18\text{ozs. per yard}}{16\text{ozs. per pound.}} = 45\text{lbs. weight of piece.}$$

$$45\text{lbs.} - 25\text{lb. warp} = 20\text{lbs. weft net or bleached weight.}$$

$$20\text{lbs.} \times \frac{100}{92 \cdot 5} = 21 \cdot 62\text{lbs. grey weight of weft.}$$

$$\frac{21 \cdot 62\text{lbs.}}{1 \cdot 35 \text{ spyndle}} = 16\text{lbs. per spyndle weft.}$$

Example XLII.—36 porter, 40in. cream sheeting, 9½ozs. per yard, 42 picks per inch; reed width, 43in.; warp length, 90 yds.; finished cloth length, 82 yds.;

warp, 2¾lbs. flax, which with the weft loses 10 per cent. in creaming.

Warp.

$$\frac{36 \text{ porter} \times 20 \times 43\text{in.} \times 2 \text{ threads per split}}{37} = 1{,}673, \text{ say } 1{,}672 \text{ thrds.}$$

$$\frac{1{,}672 \text{ threads} \times 90 \text{ yds.} \times 2\tfrac{3}{4}\text{lbs.} \times 90}{14{,}400 \text{ yds. per spyndle} \quad \times \underset{\text{\% waste in creaming.}}{100}} = 25\cdot86\text{lbs. warp.}$$

Weft.

$$\frac{42 \text{ picks} \times 43\text{in.} \times 82 \text{ yds.}}{14{,}400 \text{ yds.}} = 10\cdot28 \text{ spyndles weft.}$$

Weight of Piece.

$$\frac{82 \text{ yds.} \times 9\tfrac{1}{2}\text{ozs.}}{16\text{ozs.}} = 48\cdot69\text{lbs.}$$

48·69 − 25·86lbs. warp = 22·83lbs. weft (creamed weight).

$$\frac{22\cdot83 \times 100}{90} = 25\cdot37\text{lbs. grey weight of weft.}$$

$$\frac{25\cdot37\text{lbs.}}{10\cdot28 \text{ spyndles}} = 2\cdot47\text{lbs., say } 2\tfrac{1}{2}\text{lbs. per spyndle weft.}$$

Example XLIII.—To find the yarns necessary for a 36in. plain brown linen, 92 yds. to weigh about 40lbs., reed 7^{00}, 40in. scale, with seven shots on the glass finished; contraction from reed to finished width, and from warp length to finished length, 8 per cent. in each case.

In the two previous examples the count of the warp is stated, but in the above example both counts are unknown. In such a case it is obvious that theoretically there is an infinite number of solutions, but in dealing

with a plain linen cloth, woven approximately square, it is usual to have the yarns about equal in counts. Since weft, however, is usually softer spun than warp, and therefore appears more bulky to the eye, it is usual (where a difference in the counts is necessary) to make the weft the lighter of the two yarns. The general method of procedure in such cases is to find by calculation the total quantity of yarn in the web, and from this determine its average count. Since the lea count is required in the above case it will be most convenient to express the quantity of the yarn in leas.

Warp.

$$\overbrace{\left(\frac{\underset{\text{Reed.}}{700} \times \underset{\text{Thds. per split}}{2}}{40}\right)}^{\text{Threads per inch.}} \times \left(\frac{\overset{\text{Reed width.}}{36\text{in.} \times 100}}{92}\right) \times \overbrace{\left(\frac{\overset{\text{Cloth.}}{92\text{ yds.}} \times 100}{\underset{\text{\% contraction.}}{92}}\right)}^{\text{Warp length.}}$$

$$\times \frac{1}{300 \text{ yds. per lea}} = \underset{\text{Leas warp.}}{456 \cdot 52.}$$

Weft.

$$\left(\frac{\overset{\text{Shots per inch.}}{7 \times 200}}{37}\right) \times \left(\frac{\overset{\text{Reed width.}}{36\text{in.} \times 100}}{92}\right) \times \frac{\overset{\text{Cloth length.}}{92 \text{ yds.}}}{300 \text{ yds.}} = 454 \cdot 05 \text{ leas weft.}$$

456·52 leas warp + 454·05 leas weft = 910·57 leas in all.

$$\frac{910 \cdot 57 \text{ leas}}{40\text{lbs.}} = 22 \cdot 76 \text{ leas per pound.}$$

Assuming 22 leas warp and 24 leas weft, the weight, without making any allowance for increase due to dressing, would be as follows :—

$$\frac{456 \cdot 52 \text{ leas}}{22 \text{ leas per pound}} = 20 \cdot 75\text{lbs. warp.}$$

$$\frac{454 \cdot 05 \text{ leas}}{24 \text{ leas per pound}} = 18 \cdot 92\text{lbs. weft.}$$

$$20 \cdot 75\text{lbs. warp} + 18 \cdot 92\text{lbs. weft} = 39 \cdot 67\text{lbs. in all.}$$

If an increase of 5 per cent. in the weight of the warp, due to dressing, is assumed, then

$$20 \cdot 75\text{lbs. warp} \times \frac{105}{100} = 21 \cdot 78\text{lbs. of dressed warp;}$$

and the total weight of the piece becomes—

$$21 \cdot 78 + 18 \cdot 92 = 40 \cdot 70\text{lbs.}$$

Example XLIV.—To calculate the quantity of warp and weft necessary for 10 pieces grass-bleached pillow linen, 40in. wide, and counting in the finished state 63 warp threads and 70 weft threads per inch; warp length, 70 yds.; cloth length, 60 yds. per piece; warp, 30's lea; weft, 35's lea. To state also the weight per yard finished, assuming that both warp and weft lose 20 per cent. in bleaching from the grey yarn to the bleached cloth. Reed width, 44in. Add 3 per cent. to all quantities for waste allowance.

In the above example the sett of the cloth is given in threads per inch in the finished condition. The total number of threads in the width will therefore be 63 threads per inch × 40in. wide = 2,520 threads in all.

Warp.

$$\frac{\overset{\text{Threads.}}{(63 \times 40\text{in.})} \times 70 \text{ yds.} \times 10 \text{ pieces}}{60{,}000 \text{ yds. per bundle}} = 29 \cdot 4 \text{ bundles warp net.}$$

Weft.

$$\frac{70 \text{ picks} \times \overset{\text{Reed width.}}{44\text{in.}} \times 60 \text{ yds.} \times 10 \text{ pieces}}{60{,}000 \text{ yds.}} = 30 \cdot 8 \text{ bundles weft net.}$$

Weight of Warp.

$$\frac{29 \cdot 4 \text{ bundles} \times 200 \text{ leas per bundle} \times \underset{\substack{\text{\% waste}\\ \text{in bleaching.}}}{80}}{30 \text{ leas per pound} \times 100} = 156 \cdot 8\text{lbs.}$$

Weight of Weft.

$$\frac{30 \cdot 8 \times 200 \times 80}{35 \text{ leas} \times \underset{\substack{\text{\% waste}\\ \text{in bleaching.}}}{100}} = 140 \cdot 8\text{lbs.}$$

156·8lbs. warp + 140·8lbs. weft = 297·6lbs. total weight of ten pieces.

$$\frac{297 \cdot 6\text{lb.} \times 16\text{ozs.}}{10 \text{ pieces} \times 60 \text{ yds. each}} = 7 \cdot 93\text{ozs. per yard.}$$

With the 3 per cent. added there is for the total quantities :—

$$29 \cdot 4 \text{ bundles} \times \frac{103}{100} = 30 \cdot 282 \text{ bundles warp gross.}$$

$$30 \cdot 8 \text{ bundles} \times \frac{103}{100} = 31 \cdot 724 \text{ bundles weft gross.}$$

It is worthy of note that the weight in the above calculation is determined before adding the 3 per cent. allowance to quantities for waste. The reason for this step will be sufficiently clear, since the quantity so added never actually enters the cloth, but is simply allowed in view of the waste which would take place in the various preparatory processes of winding, warping, and dressing.

Example XLV.—A 24in. checked union glass cloth contains 48 warp threads and 52 weft threads per inch, and weighs 4ozs. per yard. The order of warping and wefting is 18 white, 2 blue (the number of threads of warp and the repeats being considered, and selvages arranged accordingly). The contraction from reed to finished width is assumed to be 6 per cent., and from

warp to finished cloth 10 per cent., and the counts and quantities of the yarns necessary calculated for 20 pieces of 72 yds. each. All the warp and the blue weft is cotton, while the white weft is lea yarn of nearest equal count in the bleached conditions. The cotton yarns lose, say, 7½ per cent., and the lea yarns, 20 per cent., in bleaching, dyeing, &c. Add 4 per cent. to quantities for waste allowances.

As in Example XLIII., it will be most convenient to determine the average bleached count from the quantity of yarn in one piece, and then arrange the true or grey counts of the warp and weft yarns. Since the warp is cotton, the quantity will be expressed in cotton hanks.

Warp.

$$\frac{48 \text{ threads} \times 24\text{in.} \times \overbrace{72 \text{ yds.}}^{\text{Warp length.}} \times 100}{840 \text{ yds. per hank} \times \underbrace{90}_{\%\text{ contraction.}}} = 109 \cdot 72 \text{ hanks.}$$

Weft.

$$\frac{52 \text{ picks} \times \overbrace{24\text{in.}}^{\text{Reed width.}} \times 100 \times 72 \text{ yds.}}{840 \times \underbrace{94}_{\%\text{ contraction.}}} = 113 \cdot 80 \text{ hanks.}$$

$$109 \cdot 72 \text{ hanks warp} + 113 \cdot 80 \text{ hanks weft} = 223 \cdot 52 \text{ hanks.}$$

$$\frac{72 \text{ yds. cloth} \times 4\text{ozs. per yard}}{16\text{ozs. per pound.}} = 18\text{lbs.}$$

$$\therefore \frac{223 \cdot 52 \text{ hanks}}{18\text{lbs.}} = 12 \cdot 42 \text{ hanks per pound cotton bleached, and,}$$

$$12 \cdot 42\text{'s bleached} \times \frac{\overbrace{92\frac{1}{2}}}{\underbrace{100}_{\%\text{ loss in bleaching.}}} = 11 \cdot 49, \text{ say } 12\text{'s cotton grey.}$$

Lea Count.

$$\frac{12\cdot42 \text{ hanks per pound} \times 840 \text{ yds. per hank}}{300 \text{ yds. per lea}} = 34\cdot776$$

leas per pound bleached.

$$34\cdot776 \text{ leas} \times \underset{\substack{\%\text{ loss in}\\ \text{bleaching.}}}{\frac{80}{100}} = 27\cdot82, \text{ say } 28 \text{ lea grey.}$$

In calculating the quantities of warp and weft it is necessary to observe that a portion of each is blue. In the warp this will be as follows :—

24in. wide × 48 threads per inch = 1,152 threads in all.

1,152 threads ÷ 20 threads per repeat = 57^{12} repeats.

57 × 2 = 114 threads blue.

1,152 − 114 = 1,038 threads bleached.

$$\frac{114 \text{ threads} \times \overset{\text{Warp length.}}{72 \text{ yds.}} \times 100 \times 20 \text{ pieces} \times 104}{\underset{\text{Yards per lb.}}{840 \times 12} \times 90 \times \underset{\%\text{ waste.}}{100}} = 18\cdot82\text{lbs.}$$

12's blue cotton warp.

$$\frac{1{,}038 \text{ threads} \times 72 \text{ yds.} \times 100 \times 20 \text{ pieces} \times 104}{840 \times 12 \times 90 \times 100} =$$

171·35lbs. 12's bleached cotton warp.

In the weft $\frac{2}{20}$ or $\frac{1}{10}$ of the whole is blue cotton.

$$\frac{52 \text{ picks} \times \overset{\text{Reed width.}}{24\text{in.}} \times 100 \times 72 \text{ yds.} \times 20 \text{ pieces} \times 104}{94 \times 60{,}000 \text{ yds.} \times \underset{\%\text{ waste.}}{100}} =$$

33·14 bundles in all.

33·14 bundles × $\frac{9}{10}$ = 29·83 bundles of 28's lea bleached weft.

$$\frac{33\cdot14 \text{ bundles} \times 60{,}000 \times 1}{840 \text{ yds.} \times 12 \times 10} = 19\cdot73\text{lbs. 12's blue cotton}$$

weft.

Of the great variety of linen fabrics produced with a few shafts by tappet mechanism, huckaback has probably

been the most successful; and enormous quantities, as well as varieties, of piece goods and cloths of this type are still made.

Originally the yarns used in the fabrics were all flax, but modern requirements and fluctuations in the price of raw materials, and especially the low price of cotton which obtained a few years ago, encouraged a liberal use of yarns of this fibre in such goods. It is now possible to obtain this particular class of fabric composed entirely of flax, of cotton, or a mixture of both. In the latter class the composition may be cotton warp and flax weft, or flax warp and cotton weft, or the warp may be composed partly of flax and partly of cotton with flax weft. The peculiarity of the weave is very suitable for the latter combination, and an example of this kind is given below.

Example XLVI.—A 27in. bleached union huckaback, 45 porter (reeded two and three threads alternately in a 36-porter reed); two-fifths of the warp 20's line ¾ bleached, and three-fifths 2/16's bleached cotton; weft, 18's tow ¾ bleached; losses in bleaching, 8 per cent. in the line warp, 12 per cent. in the tow weft, and 6 per cent. in the cotton warp; warp length = 80 yds.; 72 yds. finished cloth, the picks in this condition being 55 per inch; 10 per cent. contraction from loom to finished width. To find the actual weight of yarn in the piece and the weight per yard of the fabric. (Note: Warps for this class of fabric are sometimes reeded two threads per split throughout.)

Warp.

$$\frac{\left(\frac{\overset{\text{Splits per inch.}}{45\text{ porter}}\times 20}{37}\right)\times\overset{\text{Threads per split.}}{2}\times\overset{\text{Reed width.}}{27\text{in.}}\times 100}{\underset{\%\text{ contraction.}}{90}} = 1{,}460 \text{ threads.}$$

1,460 threads $\times\ \frac{2}{5}$ proportion of warp $=$ 584 threads of 20's line.
1,460 ,, $\times\ \frac{3}{5}$,, ,, $=$ 876 ,, 2/16's cotton.

$$\frac{584 \text{ threads}\times 80 \text{ yds.}\times 92}{20 \text{ leas}\times 300 \text{ yds. per lea}\times\underset{\%\text{ waste in bleaching.}}{100}} = 7\cdot16\text{lbs. 20's line warp per piece.}$$

$$\frac{876 \text{ threads}\times 80 \text{ yds.}\times 94}{8\times 840\times\underset{\%\text{ waste in bleaching.}}{100}} = 9\cdot80\text{lbs. 2/16's cotton warp per piece.}$$

Weft.

$$\frac{55 \text{ picks per inch}\times\overset{\text{Reed width.}}{27\text{in.}}\times 100\times 72 \text{ yds.}\times 88}{18 \text{ leas}\times 300 \text{ yds. per lea}\times 90\times\underset{\%\text{ waste in bleaching.}}{100}} = 19\cdot36\text{lbs.}$$

18's tow weft per piece.

$7\cdot16\text{lbs.} + 9\cdot80\text{lbs.} + 19\cdot36\text{lbs.} = 36\cdot32\text{lbs.}$ per piece of 72yds.

$$\frac{36\cdot32\text{lbs.}\times 16\text{ozs.}}{72 \text{ yds.}} = 8\cdot07\text{ozs. per yard.}$$

Example XLVII.—An 18in. fancy crash towelling, 8^{00} reed, 40in. scale; warp, 14's bleached line and 2/20's cotton (fast dyes); weft, 10's tow changed, 42 picks per inch; reed width, 19in.; warp length, 80yds.; cloth length, 70yds. To calculate the quantities of lea yarn in bundles, and the weight of cotton yarn, neglecting the change due to dyeing. The fancy cotton stripe to be arranged as indicated in Fig. 5, and composed as follows:

8	threads	2/20's indigo cotton	=	2 splits.
4	,,	14's line	=	2 ,,
8	,,	2/20's indigo cotton	=	2 ,,
12	,,	14's line	=	6 ,,
12	,,	2/20's Turkey-red cotton	=	3 ,,
12	,,	14's line	=	6 ,,
8	,,	2/20's indigo cotton	=	2 ,,
4	,,	14's line	=	2 ..
8	,,	2/20's indigo cotton	=	2 ,,
				27 splits for stripe.

27 splits per stripe × 4 stripes = 108 splits in all.

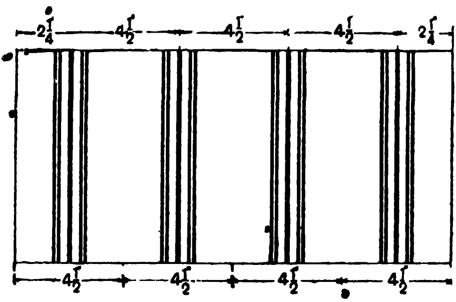


FIG. 5.

The 14's line is, as shown above, reeded two threads per split, while four threads of the 2/20's cotton are put into each split. The weave for the ground of fabric to be a fancy crape; the stripe to be in warp rib.

Warp.

$$\frac{800 \text{ splits} \times 19\text{in.}}{40\text{in.}} = 380 \text{ splits in all.}$$

380 splits − 108 splits in stripes = 272 splits for ground.

$$\frac{272 \text{ splits}}{4 \text{ patterns}} = 68 \text{ splits between stripes.}$$

16 splits × 4 patterns =	64	splits of	14's line in stripes.	
68 ,, × 4 ,, =	272	,,	,,	ground.
	336 (total splits of 14's line).			

272 splits + (16 splits × 4 patts.) = 336 splits line warp × 2 = 672 thds.
8 ,, × 4 ,, = 32 ,, ind. cotton × 4 = 128 ,,
3 ,, × 4 ,, = 12 ,, Trk.red cot. × 4 = 48 ,,

Total threads = 848

$$\frac{672 \text{ threads} \times 80 \text{ yds.}}{60{,}000 \text{ yds. per bundle}} = 0 \cdot 896 \text{ bundle 14's bleached line per piece.}$$

$$\frac{128 \text{ threads} \times 80 \text{ yds.}}{\underset{(2/20)}{10 \text{ hanks}} \text{ per lb.} \times 840 \text{ yds. per hank}} = 1 \cdot 22\text{lbs. 2/20's indigo cotton.}$$

$$\frac{48 \text{ threads} \times 80\text{yds.}}{\underset{(2/20)}{10 \text{ hanks}} \text{ per pound} \times 840 \text{ yds. per hank}} \doteq 0 \cdot 46\text{lbs. 2/20's Turkey-red cotton.}$$

Weft.

$$\frac{42 \text{ picks per inch} \times 19\text{in.} \times 70 \text{ yds.}}{60{,}000 \text{ yds.}} = 0 \cdot 931 \text{ bundle of 10's tow weft per piece.}$$

It will be observed that the above quantities are net, no allowance being made for waste in any of the preparatory processes. The complete pattern of the above warp would appear as under :—

White	8	4	12	12	4	68	= 168 × 4	patterns	= 672 threads.
Blue	8	8			8	8	= 32 × 4	,,	= 128 ,,
Red			12				= 12 × 4	,,	= 48 ,,
							212		848 threads.

Example XLVIII.—A 58in. 3-leaf striped mattress tick with two "lettered" or "name" stripes of 5-leaf satin, each stripe to be 1½in. broad, and arranged in the manner indicated in Fig. 6. Reed 6^{00}, 40in. scale; warp, 16's line grey and 2/16's Turkey red and white cotton, both reeded three threads per split; the stripes for the name to be composed of 2/20's Turkey-red cotton, 5 threads per split; the letters to be developed in 5-leaf weft satin on a 5-leaf warp ground; weft, 3lbs. per

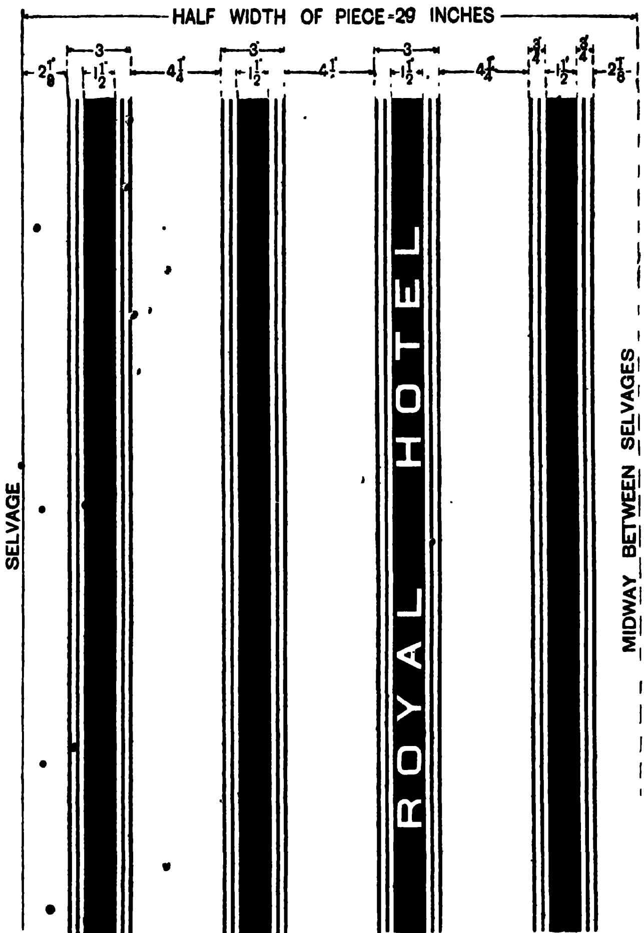

HALF WIDTH OF PIECE = 29 INCHES
SELVAGE
MIDWAY BETWEEN SELVAGES
ROYAL HOTEL

FIG. 6.

spyndle jute, half-bleached, 40 picks per inch; 72yds. of cloth from 80yds. of warp; reed width, 61in. To calculate the necessary quantities of the various yarns per piece, adding 3 per cent. for waste allowance, but neglecting any change due to dyeing, bleaching, &c.

The warping order for the stripes is as follows :—

6	threads	2/16's Turkey-red	cotton	=	2	splits
12	„	2/16's bleached	„	=	4	„
6	„	2/16's Turkey-red	„	=	2	„
12	„	2/16's bleached	„	=	4	„
69	„	2/16's Turkey-red	„	=	23	„
12	„	2/16's bleached	„	=	4	„
6	„	2/16's Turkey-red	„	=	2	„
12	„	2/16's bleached	„	=	4	„
6	„	2/16's Turkey-red	„	=	2	„
					47	splits in one stripe,

47 splits per stripe $\times$ 8 stripes = 376 splits of stripe in all.

(Note: In the centre part of the two "name" stripes the 69 threads of 2/16's cotton would be replaced by 115 threads of 2/20's Turkey-red cotton—*i.e.*, 23 splits $\times$ 5 threads per split = 115 threads.)

Warp.

$$\frac{600 \text{ splits} \times 61\text{in.}}{40\text{in.}} = 915 \text{ splits in the full width.}$$

915 splits − 376 splits for 8 stripes = 539 splits for ground.

$$\frac{539 \text{ ground splits}}{8 \text{ patterns}} = 67 \text{ splits between each pair of stripes}$$

with 3 splits over, which may be utilised for the selvages. Say, 536 splits (67×8) of line warp.

67 splits	× 8 patterns	= 536 splits	× 3 threads	=	1,608 threads 16's line grey.
31 ,,	× 6 ,,	} = 202 ,,	× 3 ,,	=	606 threads 2/16's Turkey-red cotton.
8 ,,	× 2 ,,				
16 ,,	× 8 ,,	= 128 ,,	× 3 ,,	=	384 threads 2/16's bleached cotton.
23 ,,	× 2 ,,	= 46 ,,	× 5 ,,	=	230 threads 2/20's Turkey-red cotton.
		912 splits, or	....		2,828 threads.

$$\frac{1{,}608 \text{ threads} \times 80 \text{ yds.} \times 103}{60{,}000 \text{ yds. per bundle} \times \underset{\substack{\%\text{ waste}\\ \text{allowance.}}}{100}} = 2 \cdot 208 \text{ bundles 16's line warp.}$$

$$\frac{606 \text{ threads} \times 80 \text{ yds.} \times 103}{8\text{'s} \times 840 \text{ yds.} \times 100} = 7 \cdot 43\text{lbs. 2/16's Turkey-red cotton.}$$

$$\frac{384 \text{ threads} \times 80 \text{ yds.} \times 103}{8\text{'s} \times 840 \text{ yds.} \times 100} = 4 \cdot 71\text{lbs. 2/16's bleached cotton.}$$

$$\frac{230 \text{ threads} \times 80 \text{ yds.} \times 103}{10\text{'s} \times 840 \text{ yds.} \times 100} = 2 \cdot 25\text{lbs. 2/20's Turkey-red cotton.}$$

Weft.

$$\frac{40 \text{ picks per inch} \times 61\text{in.} \times 72 \text{ yds.} \times 103}{14{,}400 \text{ yds. per spyndle} \times 100} = 12 \cdot 57 \text{ spyndles 3lbs. half-bleached jute.}$$

The complete pattern for the warp would be the following:—

A	16's grey ..	100					101	= 201 × 6 patts.	=	1,206 thds.
	2/16's red ..		6	6	69	6	6	= 93 × 6 ,,	=	558 ,,
	2/16's white		12	12		12	12	= 48 × 6 ,,	=	288 ,,
								342		2,052 thds.

B	16's grey ..	100						101	=201 × 2 patts.	=402 thds
	2/16's red..		6	6			6	6	= 24 × 2 ,,	= 48 ,,
	2/20's red..				115				=115 × 2 ,,	=230 ,,
	2/16's white		12	12		12	12		= 48 × 2 ,,	= 96 ,,
									388	776 thds

Two patterns of A or 684 threads.
One pattern of B or 388 ,,
Two patterns of A or 684 ,,
One pattern of B or 388 ,,
Two patterns of A or 684 ,,

2,828 threads.

This type of lettered weaving—viz., developing the letters in weft satin on a coloured warp ground— is extensively employed in one, two, and three striped glass, tea, and other household cloths. The lettering in some cases indicates the purpose for which the cloths are intended, and in others the name of the hotel, institution, or firm for which they are woven. Bath and lavatory towels are in many cases treated in a similar manner.

Example XLIX.—A 4/4 (36in.) blue and white 5-leaf satin tick, 45-porter reed, 3 threads per split; warp, 10's blue and 10's white cotton; weft, 20's lea tow, ¾ bleached, 52 picks per inch; length of warp, 80yds.; cloth length, 70 yds.; reed width, 39in. To calculate the net quantities of warp and weft per piece, also the weight per yard, assuming that the cotton warp loses 5 per cent. and the tow weft 12 per cent. of their weight in bleaching, dyeing, &c. Arrangement of threads :—

White 15 3 3 15 3 3 =42 thds. ÷ 3 thds. per split = 14 splits white per repeat.
Blue .. 3 15 3 6 3 6 = 36 ,, ÷ 3 ,, per split = 12 splits blue per repeat.

14 + 12 = 26 splits per repeat.

Warp.

$$\frac{\overset{\text{Splits per inch.}}{45 \text{ porter}} \times 20 \text{ splits} \times 39\text{in.}}{37\text{in.}} = 949 \text{ splits in full width.}$$

$$\frac{949 \text{ splits}}{26 \text{ splits per repeat}} = 36\tfrac{1}{2} \text{ repeats.}$$

The following is suggested as a suitable arrangement of the pattern for the warping :—

White.	6		3			3	15	3	3	15	3			3	6	
Blue ..		3		7	8	3		6	3	6		3	7	8		3
	19 threads at selvage.				78 threads × 36 repeats									20 threads at selvage.		

(42 thds. × 36 repeats) + 18 thds. at selvages = 1,530 thds. of white.
(36 „ × 36 „) + 21 „ „ = 1,317 „ blue.

$$\frac{1{,}530 \text{ threads} \times 80 \text{ yds.} \times 95}{10\text{'s} \times 840 \text{ yds.} \times \underset{\text{\% waste in bleaching.}}{100}} = 13{\cdot}84\text{lbs. 10's bleached cotton warp.}$$

$$\frac{1{,}317 \text{ threads} \times 80 \text{ yds.} \times 95}{10\text{'s} \times 840 \text{ yds.} \times 100} = 11{\cdot}92\text{lbs. 10's blue cotton warp.}$$

Weft.

$$\frac{52 \text{ picks per inch} \times 39\text{in. reed width} \times 70 \text{ yds.} \times 88}{20 \text{ leas} \times 300 \text{ yds.} \times \underset{\text{\% waste in bleaching.}}{100}} = 20{\cdot}82\text{lbs. 20's lea tow weft.}$$

$$\frac{(13{\cdot}84\text{lbs.} + 11{\cdot}92\text{lbs.} + 20{\cdot}82\text{lbs.})\ 16\text{ozs.}}{70 \text{ yds.}} = 10{\cdot}65\text{ozs. per yard.}$$

To conclude this series of examples of typical linen fabrics there has been selected one of the finer class of damask tablecloths woven by a twilling jacquard with the 8-thread satin twills (popularly known as "double damask" in contra-distinction to the so-called "single damask," which is woven with the 5-thread satins). For

this type of cloth in 8/4 (eight-quarter) or 72in. wide it is not unusual to have three twilling jacquards, each with a capacity of 1,200 hooks, over each loom. In cloths of this grade the relative numbers of picks and threads are usually as 3 to 2, hence it is necessary to increase the picks per card in relation to the hooks per needle of the jacquard, or to proportionately increase the weft lines of the design paper in relation to those of the warp. For example, a cloth containing, say, 96 warp threads and 144 weft threads per inch finished, if woven by a jacquard having two hooks per needle, may have the design painted upon 12-by-12 paper, and woven with 3 picks per card, or it may be painted upon 12-by-18 paper, and then only two picks per card will be necessary. The latter method would undoubtedly give the better result so far as the contour of the pattern is concerned, but the design would be more expensive to paint, besides requiring 50 per cent. more cards than the former method.

Example L.—To calculate the net quantity in bundles of warp and weft in one piece of 72in. fine bleached damask, 96 warp threads and 144 weft threads per inch in the finished state; warp length, 50 yds.; cloth length, 48 yds.; 7 per cent. contraction from reed to finished width. To estimate the weight of the cloth per square yard, warp made from 50's line creamed, and weft 75's line creamed, assuming the warp and weft to both waste 25 per cent. in the creaming and subsequent bleaching processes.

Warp.

$$\frac{96 \text{ threads} \times 72\text{in.} \times 50 \text{ yds.}}{60{,}000 \text{ yds. per bundle}} = 5 \cdot 76 \text{ bundles 50's line creamed net.}$$

Weft.

$$\frac{144 \text{ picks} \times \overset{\text{Reed width.}}{72\text{in.}} \times 100 \times 48 \text{ yds.}}{60{,}000 \text{ yds.} \times \underset{\text{\% contraction.}}{93}} = 8\cdot92 \text{ bundles 75's line creamed net.}$$

$$\frac{5\cdot76 \text{ bundles} \times 200 \text{ leas per bundle}}{50 \text{ leas per pound}} = 23\cdot04\text{lbs. of warp in grey state.}$$

$$\frac{8\cdot92 \text{ bundles} \times 200 \text{ leas per bundle}}{75 \text{ leas per pound}} = 23\cdot79\text{lbs. of weft in grey state.}$$

23·04lbs. + 23·79lbs. = 46·83lbs. total weight in grey state.

$$\frac{46\cdot83\text{lbs.} \times 16\text{ozs.} \times 75}{\underset{\text{Square yards.}}{48 \text{ yds.} \times 2} \times \underset{\text{\% waste in creaming and bleaching.}}{100}} = 5\cdot85\text{ozs. per square yard.}$$

CHAPTER VIII.

The Prime Cost of Fabrics.

IN determining the cost of textile fabrics there are, broadly speaking, three different heads under which the various outlays or costs may be classed. These are :—

1. Cost of material.
2. Labour charges.
3. General working expenses and standing charges; these items being usually briefly referred to as "expenses."

Under the first head the items are few, usually consisting of the cost of the warp and the weft in the piece plus a certain allowance for waste in working. To determine this cost is a simple matter, since it is only necessary to know the quantity of yarn used, and the price paid per unit length or weight, according to the manner in which the yarn is purchased. With regard to head No. 2, it is well known that there are two methods or bases upon which wages are paid, viz. :—

(*a*) Piecework, or payment according to the quantity of work performed; and

(*b*) Timework, where the operative receives a fixed sum per hour or per week.

The former method is the more satisfactory, and is applied in almost every available case; it reduces to a minimum the cost of supervision, is an excellent incentive to increased production, and enables the manufacturer to obtain a very good idea of the cost of that particular part of the process. The method, however, is not free from objections, for it causes a tendency on the part of workers to allow bad work to pass; and should any inferior material happen to be introduced dissatisfaction naturally prevails. The former objection can be checked by strict supervision, the latter is an unfortunate circumstance to all concerned.

There are at least three forms in which warp yarns are bought for the jute trade:—

1. In the form of a chain, where the price per spyndle or per pound of the yarn includes the cost of winding and warping.

2. In the beamed and dressed condition ready for looming. Here the price includes the expenses involved by these processes.

3. In the form of spools, in which case the further expense of dressing requires to be added before the yarn is ready for the loom.

Jute wefts, for the ordinary fabrics, are bought for the most part in the form of cops ready for the shuttle. In fancy-jute goods, however, the further piecework charges of warp and weft winding and warping require to be added, since the yarn is usually bought in the hank condition for the purposes of dyeing. In every case all determinable costs and charges should be placed under heads 1 and 2.

In the linen industry both warp and weft yarns are invariably purchased in the hank condition, and either grey or bleached. If grey, it will, of course, be necessary to add a further charge for boiling, changing, bleaching, or whatever process the yarn goes through before weaving. In general, the preparatory processes of warp and weft winding, warping and dressing, are piecework, although the latter is sometimes paid according to time. Chain beaming, drawing-in, and reeding, and tying-on, in both industries are sometimes paid by one method and sometimes by the other. Weaving is always piecework, while the loom tenter is often paid according to a scheme arranged partly under both systems. Where, however, the total wage cannot be classed under piecework, the whole amount should be included under head No. 3. As to the actual wages paid, there is, unfortunately, no recognised standard list in either of the industries. In all the examples an endeavour will be made to illustrate the various bases of payment, although the figures given must not be taken as indicative of an average, or of any practice.

Under division No. 3 must manifestly be placed every item of expenditure in the production of the fabric which has not already been taken into account under heads 1 and 2. Head No. 3 is thus very comprehensive, containing such items as: All wages paid other than those included under head No. 2; salaries of administrative and clerical staff, engineers, designers, and all so-called non-productive persons; interest on capital, allowance for depreciation in buildings and machinery, feu-duty or rent, taxes, and insurances; coal, water, gas, and electrical expenses; expenses of

warehouse and sample department, if any; stores and renewals of all kinds, jacquard cards, &c.; in short, every item of expenditure which may not be termed a capital charge.

Since it would be extremely difficult, if not altogether impossible, to allocate the proportion of such expenditure entailed by the production of each class of fabric per yard or otherwise, the general method is adopted of noting such total expenditure per annum or other suitable period, and comparing it with the total wages paid for weaving during the same period. From this comparison a general deduction is made that the expenses of production, other than those piecework charges which may be definitely calculated, are equal to a certain proportion of the weaving rate. From the nature of the case it is obvious that this proportion will vary considerably according to the class of fabric; and that whilst for some plain and simple fabrics, such as the ordinary run of jute goods, it may be only equal to, or even less than, the weaving rate, yet for other fabrics, such as those produced by dobby and jacquard mechanism, in conjunction with box looms, this amount may reach two or even three times the weaving wage. For jute and linen fabrics it is usually sufficient to add from 1 to 1½ time the weaving rate, but such addition will be determined by each individual manufacturer on lines similar to those suggested above. Where goods are sold finished and made up this further item has to be added. Should finishing be performed in the factory it may be difficult to separate the cost of this process from that of the others, and in such cases it would probably be included with them; but where the goods

are finished outside it is generally possible, and always preferable, to add the cost of finishing as a separate item. At this point the finished cost is reached, but beyond this, agents' commission, carriage, and profit have to be added to obtain the selling price.

With a view to simplifying matters in the following calculations, advantage will be taken of those examples of fabrics already given from Example XXXV. onward. In the majority of these examples it will be observed that, due to the nature of the calculations, no allowance is made for waste in the various processes. In considering the cost, however, such allowance is always necessary in the case of the weft, and generally necessary in the warp, the exceptions in the latter being the cases where the warp has been purchased in the chain or in the beamed condition. For the finer classes of jute and linen fabrics a waste allowance of 3 to 4 per cent. is usually considered sufficient, but for coarse jute and tow yarns it may be necessary in some cases to increase this to 5 or even to 6 per cent.

Example LI.—To find the cost per yard of an 11-porter, 40in. hessian, $10\frac{1}{2}$ozs. per yard, 13 shots per inch finished. Warp, 9lbs. per spyndle, dressed, at $2\frac{3}{8}$d. per lb. Weft, $8\frac{1}{2}$lbs. per spyndle at 1s. $6\frac{1}{2}$d. per spyndle. Weaving, 1s. $5\frac{1}{2}$d. per 108 yds. of warp. Other expenses equal to weaving. Finishing and making up, $\frac{1}{12}$d. per yard. Finished length, 105 yds. Reed width, $43\frac{1}{2}$in.; add 3 per cent. to weft quantity for waste.

Warp.

Threads per inch.	Reed width.	Warp length.		Pence.

$$\frac{11 \text{ porter} \times 20 \times 2 \times 43\tfrac{1}{2}\text{in.} \times 108 \text{ yds.} \times 9\text{lb.}}{37 \times 14{,}400 \text{ yds. per spyndle}} = 34{\cdot}92\text{lb. at } 2\tfrac{3}{8} = 82{\cdot}93$$

Weft.

$$\frac{13 \text{ shots} \times 43\tfrac{1}{2}\text{in. (reed width)} \times 105 \text{ yds. (cloth length)} \times 103}{14{,}400 \text{ yds. per spyndle} \times 100 \text{ (\% waste)}} = 4{\cdot}25 \text{ spyndles at 1s. } 6\tfrac{1}{2}\text{d.} = 78{\cdot}62$$

Weaving		=17·50
Expenses		=17·50
Finishing	105 yds. at $\frac{1}{12}$d. =	8·75
		205·30

$$\frac{205{\cdot}3}{105 \text{ yds.}} = 1{\cdot}955\text{d. per yard; say } 1\tfrac{7}{8}\text{d. per yard.}$$

Example LII.—To calculate the cost per yard of a 10-porter, 45in., 20ozs. D.W. tarpauling, $12\frac{1}{2}$ shots per inch finished. Warp, $8\frac{1}{2}$lbs. per spyndle, at 1s. $6\frac{3}{8}$d. per spyndle on spools. Weft, 14lbs. per spyndle, in cops, at $1\frac{7}{8}$d. per pound. Dressing 2d., and weaving 1s. 7d. per cut of 108 yds. warp. Expenses same as weaving rate. Finishing, $\frac{1}{16}$d. per yard. Cloth length, 103 yds. Reed width, 48in. Add 1 per cent. to warp for dresser's waste, and 3 per cent. to weft for weaver's waste.

Warp.

$$\frac{10 \text{ porter} \times 20 \times 4 \text{ (threads per inch)} \times 48\text{in. (reed width)} \times 108 \text{ yds. (warp length)} \times 101 \text{ (waste allow'ce)}}{37\text{in.} \times 14{,}400 \text{ yds.} \times 100} =$$

	Pence.
7·86 spyndles at 1s. $6\frac{3}{8}$d. =	144·43

Weft.

$$\frac{12\tfrac{1}{2} \text{ shots} \times 48\text{in. (reed width)} \times 103 \text{ yds. (cloth length)} \times 14\text{lbs.} \times 103 \text{ (waste allow'ce)}}{14{,}400 \text{ yds. per spyndle} \times 100} = 61{\cdot}88\text{lbs at } 1\tfrac{7}{8}\text{d} = 116{\cdot}02$$

Dressing	=	2·00
Weaving	=	19·00
Expenses	=	19·00
Finishing	103 yds. at $\frac{1}{16}$d. =	6·44
		306·89

$$\frac{306{\cdot}89\text{d.}}{103 \text{ yds.}} = 2{\cdot}98\text{d.; say, 3d. per yard.}$$

Example LIII.—To find the cost per yard of a 10-porter, 28in., 20ozs. twilled sacking, $10\frac{1}{2}$ shots per inch finished. Warp, 8lbs. per spyndle, in chain, at $2\frac{1}{4}$d. per pound. Weft, 32lbs. per spyndle in cops, at $1\frac{1}{16}$d. per pound. Weaving, 1s. 4d. per cut, of 108 yds. warp. Expenses ditto. Finishing $\frac{1}{18}$d. per yard. Cloth length, 102 yds. Reed width, $29\frac{1}{2}$in. Allow 4 per cent. for weaver's waste on the weft only.

Warp.

$$\frac{10 \text{ porter} \times 20 \times 6}{37} \times \frac{29\frac{1}{2}\text{in.} \times 108 \text{ yds.} \times 8\text{lbs.}}{14{,}400 \text{ yds.}} =$$

Pence.

57·40lbs. at $2\frac{1}{4}$ = 129·15

Weft.

$$\frac{10\frac{1}{2} \text{ shots} \times 29\frac{1}{2}\text{in} \times 102 \text{ yds} \times 32\text{lbs}}{14{,}400 \text{ yds.}} \times \overset{\text{Waste.}}{\frac{104}{100}} =$$

73·02lbs. at $1\frac{1}{16}$d. = 123·22

Weaving	....	= 16·00
Expenses	....	= 16·00
Finishing	....................102 yds. at $\frac{1}{18}$d.	= 5·67
		290.04

$$\frac{290\cdot04\text{d.}}{102 \text{ yds}} = 2\cdot84\text{d.}; \text{ say, } 2\tfrac{10}{12}\text{d}, \text{ per yard.}$$

Example LIV.—To calculate the cost per yard of a 12-porter, 36in. imitation tapestry, 14 shots per inch. Ground warp, 11lbs. dyed and starched, at $2\frac{1}{4}$d. per pound; dyeing, $\frac{5}{8}$d. per pound extra. Pile warp, 2 ply 9lbs., dyed, at $2\frac{7}{16}$d. per pound; dyeing, $\frac{3}{4}$d. per pound extra. Weft, 11lbs., at $2\frac{1}{8}$d. per pound; dyeing, $\frac{5}{8}$d. per pound. 75 yds. of cloth from 140 yds. of pile warp, and 76 yds. of ground warp. Reed width, $36\frac{1}{2}$in. Winding, single warp at $\frac{7}{8}$d. per spyndle; twist warp at 1d. per spyndle; weft at $2\frac{3}{16}$d. per spyndle. Warping 2d. per spyndle. Weaving, 4s. 6d. Expenses, $1\frac{1}{4}$ time weaving. Add 4 per cent. to all quantities for

winding and other wastes. Note that although the yarns lose in weight in dyeing, the latter is charged upon the calculated grey weight. It is also considered convenient in practice to first calculate the price per spyndle of the various yarns in their dyed and wound conditions. Thus :—

11lbs. ground warp at ($2\frac{1}{4}$ per pound + $\frac{5}{8}$ per pound dyeing) = 2s. $7\frac{5}{8}$d. per spyndle, + $\frac{7}{8}$d. per spyndle winding = 2s. $8\frac{1}{2}$d. per spyndle.

2 × 9lbs. pile warp at ($2\frac{7}{16}$ per pound + $\frac{3}{4}$ per pound dyeing) = 4s. $9\frac{3}{8}$d. per spyndle + 1d. per spyndle winding = 4s. $10\frac{3}{8}$d. per spyndle.

11lbs. weft at ($2\frac{1}{8}$ per pound + $\frac{5}{8}$ per pound dyeing) = 2s. $6\frac{1}{4}$d. per spyndle + $2\frac{3}{16}$ per spyndle winding = 2s. $8\frac{7}{16}$d. per spyndle.

Ground Warp.

$$\underset{\text{Threads per inch.}}{\frac{12 \text{ porter} \times 20 \times 1}{37}} \times \frac{\underset{\text{Reed width.}}{36\frac{1}{2}\text{in.}} \times \underset{\text{Warp length.}}{76 \text{ yds.}}}{14{,}400 \text{ yds.}} \times \underset{\text{\% Waste.}}{\frac{104}{100}} =$$

Pence.

1·3 spyndles at 2s. $8\frac{1}{2}$d. = 42·25

Pile Warp.

$$\frac{12 \times 20 \times 2}{37} \times \frac{36\frac{1}{2}\text{in.} \times 140 \text{ yds}}{14{,}400 \text{ yds.}} \times \frac{104}{100} =$$

4·79 spyndles at 4s. $10\frac{3}{8}$d. = 279·62

Weft.

$$\frac{14 \text{ shots} \times 36\frac{1}{2}\text{in.} \times 75 \text{ yds.}}{14{,}400 \text{ yds. per spyndle.}} \times \frac{104}{100} = 2{\cdot}77 \text{ spls. at 2s. } 8\tfrac{7}{16}\text{d.} = \quad 89{\cdot}85$$

Warping	6 spyndles at 2d. =	12·00
Weaving	at 4s. 6d. =	54·00
Expenses	$1\frac{1}{4}$ × 4s. 6d. =	67·50
		545·22

$$\frac{545{\cdot}22\text{d.}}{75 \text{ yds.}} = 7{\cdot}27\text{d. per yard ; say, } 7\tfrac{5}{16}\text{d. per yard.}$$

Example LV.—To calculate the price per yard of a 34-porter, 27in. tent duck with 38 shots per inch. Warp, $4\frac{1}{4}$lbs. flax at 2s. $8\frac{3}{4}$d. per spyndle, plus 1d. per pound bleaching, or $4\frac{1}{4}$d. per spyndle, *i.e.*, 2s. $8\frac{3}{4}$d. +

4¼d. = 3s. 1d. per spyndle bleached. Weft, 4lbs. flax at 2s. 6d. + 4d. for bleaching = 2s. 10d. per spyndle. Warp length, 144 yds.; cloth length, 120 yds.; reed width, 29in. Add 4 per cent. to all quantities for waste. Warp winding, ½d. per spyndle; weft winding 1d. per spyndle; warping and dressing, 6d; weaving, 4s. 6d.; expenses, including finishing, 5s. This cloth, with from 5 to 7½ per cent. waste allowance in the yarn bleaching, will weigh from 10ozs. to 10¼ozs. per yard.

Warp.

$$\frac{\underset{\text{in reed.}}{\overset{\text{Threads per in.}}{34\text{ porter}}}\ 20 \times 2 \times \overset{\text{Reed width.}}{29\text{in.}} \times \overset{\text{Warp length.}}{144\text{ yds.}} \times \overset{\text{Waste allowance.}}{104}}{37 \times \underset{\text{Yards per spyndle.}}{14{,}400} \times 100} =$$

Pence.

11·08 spyndles warp at 3s. 1d. = 409·96

Weft.

$$\frac{38\text{ shots} \times 29\text{in.} \times \overset{\text{Cloth length.}}{120\text{ yds.}} \times \overset{\text{Waste allowance.}}{104}}{14{,}400\text{ yds. per spyndle} \times 100} =$$

9·55 spyndles weft at 2s. 10d. = 324·70

Warp winding	11 spyndles at ½d. =	5·50
Weft winding	9½ spyndles at 1d. =	9·50
Warping and dressing	=	6·00
Weaving	at 4s. 6d. =	54·00
Expenses, including finishing	at 5s. =	60·00
		869·66

$$\frac{869{\cdot}66\text{ pence}}{120\text{ yds.}} = 7{\cdot}25\text{ pence, or } 7\tfrac{1}{4}\text{d. per yard.}$$

Example LVI.—To calculate the cost per yard of a 24in. checked union glass cloth made in a 9^{00} reed, 40in. scale, with 10 shots per glass finished. Reed width, 26in.; 72 yds. of cloth from 80 yds. of warp; nine-tenths of the warp to be 12's cotton bleached at 9d. per pound—*i.e.*, 8d. per pound for the yarn plus 1d. per pound for bleaching; one-tenth of the warp to be 2/24's blue cotton at 11d. per pound; ten-elevenths

of the weft to be 30's lea bleached at 5s. 10½d. per bundle, and one-eleventh to be 2/24's blue cotton at 11d. per pound. Add 4 per cent. for waste to all yarns except the 12's bleached cotton warp. This warp would be received in chain form, but would require beaming and dressing; the blue cotton would be received in hank and would therefore require winding for both warp and weft. Winding for blue-cotton warp, 1d. per 30 hanks; cotton weft, 1d. per 20 hanks; linen weft, 1d. per 4 hanks or 48 leas; beaming and dressing, 4d.; weaving, 3s. 6d.; expenses, including finishing, 4s.; all the latter per cut of 80 yds. warp.

Warp.

Threads per in. in reed. Reed width. Warp length.

$$\frac{900 \times 2 \times 26\text{in.} \times 80 \text{ yds.}}{40 \times 840 \text{ yds.} \times 12 \text{ hanks per pound}} = 9.29\text{lbs. of cotton warp net.}$$

Weft.

Shots per inch. Reed width. Cloth length.

$$\frac{10 \text{ shots} \times 200 \times 26\text{in.} \times 72 \text{ yds.}}{37 \times 60{,}000 \text{ yds. per bundle}} = 1{\cdot}687 \text{ bundles of weft net.}$$

Pence.

$9{\cdot}29\text{lbs.} \times \frac{9}{10} =$ 8·36lbs. of 12's cotton bleached at 9d. .... = 75·24

$9{\cdot}29\text{lbs.} \times \frac{1}{10} \times \frac{104}{100} =$

0·966lbs. of 2/24's blue cotton at 11d. = 10·62

$1{\cdot}687 \text{ bundles} \times \frac{10}{11} \times \frac{104}{100} =$

1·595 bundles of 30's linen at 5s. 10½d. = 112·44

$$\frac{1.687 \text{ bdls.} \times 1 \times 60{,}000 \text{ yds.}}{11 \times 840 \text{ yds.} \times 12 \text{ hanks}} \times \frac{104}{100} =$$

0·95lbs. of 2/24's blue cotton at 11d. = 10·45

Winding blue cot. warp, 0·966lbs. × 12 hnks. × $\frac{1}{30}$d. per hank = 0·38

" " weft, 0·950lbs. × 12 " × $\frac{1}{20}$d. " = 0.57

" linen weft, 1·595 bdls. × 16⅔ " × ¼d. " = 6·65

Beaming and dressing .... = 4.00

Weaving ....at 3s. 6d. = 42·00

Expenses, including finishing .... at 4s. = 48·00

310·35

$$\frac{310{\cdot}35 \text{ pence}}{72 \text{ yds.}} = 4{\cdot}31 \text{ pence, ; say, } 4\tfrac{5}{16}\text{d. per yard.}$$

Example LVII.—To calculate the cost per yard of a 27in. bleached union huckaback. Reed 45 porter, 2 threads per split, with 55 shots per inch finished. Two-fifths of the warp to be 20's line at 8s. 3d. per bundle bleached, and three-fifths to be 2/16's cotton at 8¼d. per pound bleached. Weft, 18's lea tow at 7s. 9d. per bundle bleached. Reed width, 30in.; warp length, 80 yds.; cloth length, 72 yds. Add 4 per cent. to all for waste allowance. Winding lea warp, 2d. per bundle; and lea weft, 4d. per bundle. Winding cotton warp, 3d. per 72 hanks. Warping and dressing, 4½d. Weaving, 3s. 11d. Other expenses, 4s. 9d.

Lea Warp.

Threads per in. in reed. — Reed width. — Warp length. — Waste. — Propor. of warp.

$$\frac{45 \text{ porter} \times 20 \times 2 \times 30\text{in.} \times 80 \text{ yds.} \times 104 \times 2}{37 \times 60{,}000 \text{ yds. per bundle} \times 100 \times 5} =$$

Pence.

0·809 bdls. at 8s. 3d. = 80·09

Cotton Warp.

Threads per in. in reed.

$$\frac{45 \times 20 \times 2 \times 30\text{in.} \times 80 \text{ yds.} \times 104 \times 3}{37 \times 8\text{'s} \times 840 \text{ yds.} \times 100 \times 5} =$$

(2/16's) 10·84lbs. at 8¼d. = 89·43

Weft.

Cloth length. — Waste.

$$\frac{55 \text{ shots} \times 30\text{in.} \times 72 \text{ yds.} \times 104}{60{,}000 \text{ yds. per bundle} \times 100} =$$

2·059 bundles at 7s. 9d. = 191·48

Winding lea warp, 0·809 bundles at 2d. per bundle .... =	1·62
,, cotton warp, 10·84lbs. × 8's. = 86·72 hanks at $\frac{3}{72}$d. =	3·61
,, lea weft, 2·059 bundles at 4d. per bundle .... =	8·24
Warping and dressing .... at 4½d. =	4·50
Weaving .... at 3s. 11d =	47·00
Expenses .... at 4s. 9d. =	57·00
	482·97

$$\frac{482{\cdot}97 \text{ pence}}{72 \text{ yds.}} = 6{\cdot}71 \text{ pence; say, } 6\tfrac{3}{4}\text{d. per yard.}$$

Example LVIII.—To calculate the cost per square yard of a fine bleached damask, 72in. wide, made in a 1,200's reed, 40in. scale, 3 threads per split, and counting 27 shots per $\frac{37}{200}$ glass finished. Contraction from reed width to finished width, 7 per cent., and from warp length to cloth length, 4 per cent. Add 3 per cent. to all quantities for waste. Warp, 50's lea line boiled at 5s. 6d. per bundle; weft, 75's lea line boiled at 4s. per bundle, both less 3 per cent. discount. Warp winding, 1s. per 100 hanks; weft winding, 2s. per 100 hanks; warping, 4d. per 100 hanks; dressing, 8d. per 100 yds. warp. Weaving, 32s. per 100 yds. warp; expenses, 48s. Bleaching and finishing, $1\frac{3}{8}$d. per square yard.

Warp.

Thds. per in. in reed. Reed width. Warp length. Waste.

$$\frac{1{,}200 \times 3 \times 72 \times 100 \times 100 \text{ yds.} \times 103}{40 \times 93 \times 60{,}000 \text{ yds.} \times 100} =$$

$$11{\cdot}96 \text{ bdls.} \times 5\text{s. } 6\text{d. per bundle} \times \frac{97}{100} \text{ per cent. disct.} = 765{\cdot}68 \text{ Pence.}$$

Weft.

Shots per inch. Reed width. Cloth length. Waste.

$$\frac{27 \times 200 \times 72 \times 100 \times 96 \text{ yds.} \times 103}{37 \times 93 \times 60{,}000 \text{ yds.} \times 100} =$$

$$18{\cdot}62 \text{ bdls.} \times 4\text{s. per bundle} \times \frac{97}{100} = 866{\cdot}95$$

Warp winding	11·96 bundles	× $16\frac{2}{3}$ hanks	× $\frac{12}{100}$d.	.... =	23·92
Weft „	18·62 „	× $16\frac{2}{3}$ „	× $\frac{24}{100}$d.	.... =	74·47
Warping	11·96 „	× $16\frac{2}{3}$ „	× $\frac{4}{100}$d.	.... =	7·97
Dressing				at 8d. =	8·00
Weaving				at 32s. =	384·00
Expenses				at 48s. =	576·00
Bleaching and finishing 96 yds. × 2 = 192 yds. at $1\frac{3}{8}$d. per square yard				=	264·00
					2,970·99

$$\frac{2{,}970{\cdot}99 \text{ pence}}{96 \text{ yds.} \times 2 \text{ Square yards.}} = 15{\cdot}47 \text{ pence; say, 1s. } 3\tfrac{1}{2}\text{d. per square yard.}$$

A tablecloth of this quality, in size 2 yds. wide by $2\frac{1}{2}$ yds. long, would therefore cost $2 \times 2\frac{1}{2} = 5$ square yards at 1s. $3\frac{1}{2}$d. = 6s. $5\frac{1}{2}$d.

In jute and linen weaving, generally, the incidental expenses of production as a proportion of the weaving wage will vary very little for the different examples of any particular class of fabric. In damask weaving, however, the proportion of the expenses to the weaving rate may, on account of the design, vary considerably for cloths of the same quality. It is well known that there is a large variety of patterns introduced into any one class of such goods. In the above example, therefore, the allowance for expenses, although $1\frac{1}{2}$ times the weaving rate, is independent of the cost of the sketch or design, of the painting of same on design paper, and of the cards necessary to weave the cloth. The extra amount which should be added will obviously depend upon such considerations as :—

(*a*) The price of the sketch, which is usually independent of the size or capacity of the jacquard.

(*b*) The price of painting the design, which increases rapidly as the number of hooks employed increases, and is approximately proportional to the square of such increase, although in many cases this proportion is much exceeded.

(*c*) The number, and therefore the cost, of cards, the cutting, and the lacing are, like the painting, approximately proportional to the square of the increase in the number of hooks.

(*d*) The number of cloths to be woven may be great or small. It is quite evident that this part alone will

influence, in a great measure, the ultimate actual cost per cloth.

It is therefore considered best in such cases to add the cost of actual working only, as is done with the ordinary fabrics, and then to determine these extra amounts for each particular case.

CHAPTER IX.

THE ANALYSIS OF FABRICS.

The Analysis and Structure of Jute and Linen Fabrics.—The analysis of jute and linen fabrics, or indeed of any unfelted cloth, presents few difficulties which cannot be overcome by a little experience, and by the exercise of an ordinary amount of care and judgment. To ensure accuracy, however, especially in the finer fabrics, the student should be provided with a fine balance (maximum load about 50grms.), sensitive to 0·05 grain, with a box of weights, say from 100 grains down to 0·01 grain, and with a steel or wooden measure graduated in both British and metric systems. The chief object of most analyses is to determine the sett of the fabric, both warp and weft, together with the counts of these yarns. In addition, it is often necessary to analyse for the weave or texture, and sometimes to determine the nature and quality of the fibre. There are three general methods by which we can proceed to determine the nature of the fibre. These are :—

1. Ordinary observation.
2. Microscopical examination.
3. Chemical reactions.

With regard to the last method, many chemical tests

have from time to time been given to the public for the purpose of distinguishing between the different vegetable fibres. Most of these tests have special reference to linen and cotton, as there is a growing tendency to mix the two kinds of yarns in what are considered typical linen fabrics. Due, however, to the fact that both fibres are of practically the same chemical composition—cellulose—it is very difficult to obtain, by means of any chemical agent, a characteristic colour or feature in one fibre, which the same agent does not impart in some degree to the other. We have, on various occasions, applied several of the tests with varing degrees of success, and consider that, except when in the hands of an experienced chemist, such tests are unreliable. A list of the most important is given below.

1. The fabric is immersed in a highly-concentrated solution of sugar and common salt, then dried, and the yarns separated. Flax threads carbonise a greyish shade; cotton, black.

2. A strip of the fabric is steeped for two minutes in a boiling 50 per cent. solution of caustic potash (KOH). After wringing, washing, and separating the threads, flax is stained deep yellow, and cotton light yellow.

3. When cotton cellulose and flax cellulose are put into concentrated acids, the former is more easily affected. The fabric is washed in sodium carbonate ($Na\,CO_3$) to remove the gummy substances, dried, and immersed in concentrated sulphuric acid (H_2SO_4). The fabric becomes semi-transparent, cotton is converted into gum, while flax remains white and opaque. After

washing, neutralising with alkali, re-washing, and drying, the cotton will have entirely dissolved, and its amount may be estimated from the loss in weight.

4. A strip of fabric dried in hot air (100° C.) is steeped for several minutes in clear oil and then pressed. Flax becomes transparent and cotton remains opaque.

5. The threads and picks are removed and placed in a 1 per cent. alcoholic solution of fuchsine, washed, and then left for three minutes in ammonia. Flax threads are dyed rose-red; cotton threads are unaffected.

6. The fabric is wetted with an alcoholic solution of rosalic acid, then with caustic soda. Flax is coloured rose-red ; cotton remains white.

7. The yarns are immersed in a cold concentrated solution of caustic potash. Both threads shrink and twist, but cotton remains pale grey, while flax turns orange-yellow, This test is only applicable to unbleached goods.

A test which may be considered more of a physical than of a chemical nature, and one by which good results have been obtained, is to immerse either a single thread or a number of threads in a concentrated (say 50 per cent.) solution of caustic potash. A single thread of cotton so treated will immediately unwind and curl in a peculiar manner; while a single thread of flax unwinds much more slowly. If a few threads of the unknown fibre be plunged into the liquid, they will, if cotton, exhibit the same tendency to unwind, and in addition will twist together and appear more or less similar to a rope. On the other hand, the threads, if flax, will show only a slight tendency to unite. The

difference in the behaviour of the two fibres in such a solution may perhaps be due to the peculiar physical features of the two fibres.

As seen through the microscope, cotton resembles a flattened and twisted tube, with thickened edges, the latter having a tendency to curl inwards. This feature is evident from an examination of Fig. 7, which shows a general view of four such fibres, but it is more apparent in the cross-sectional view of similar fibres illustrated in the same figure.

Flax, when microscopically examined, shows a perfectly straight, straw-like structure, with cross markings at intervals. These marks are somewhat similar to those of a bamboo cane, and are clearly shown in Fig. 8, which is a general view of this fibre. Under high magnification numerous striations or apparent cracks appear in the cell walls. These are, however, more clearly seen if the fibre is stained, say, in a solution of iodine before being placed under the object glass of the microscope. The cross-sectional view, Fig. 8, shows that this fibre varies considerably in thickness, while its shape changes from ellipses to irregular pentagons and hexagons. In the majority of cases the central canal is very small.

A microscopical examination of the jute fibre reveals no characteristic markings, although, as in Fig. 9, faint cross marks may sometimes be detected. The fibre appears perfectly straight and straw-like, and is generally streaked in a longitudinal direction. This seems to indicate different degrees of transparency, for, when the cross section of the fibre is examined, see

Fig. 9, it is seen to be composed of a group of cells bound together by a gummy and semi-opaque substance. The longitudinal marks are probably due to this substance which joins up the different cells in the group. The central canal of the cell is rather large.

Figs. 7 to 9 are magnified about 136 diameters, and, for purposes of comparison with the actual diameters of the fibres, we have included, between each general view and section, a number of divisions, each equal to one-thousandth of an inch, magnified to the same degree.

Jute being a ligno-cellulose, is supposed to give certain characteristic colours when treated with certain chemcals, *e.g.* :—

Iodine and sulphuric acid solution turns jute yellow.

Iodine and sulphuric acid solution turns flax blue.

Phloroglucine chloride turns jute bright red.

Phloroglucine chloride has no effect on flax.

Here, again, the results are not always reliable. Fortunately, however, the jute fibre is seldom difficult to detect, nor does the necessity for doing so often arise, since it is generally manufactured in the natural or grey condition. Limited quantities of jute, as well as of flax, have at times been "woollenised" by chemical treatment, but burning affords a ready means of distinguishing between vegetable and animal fibres. The former burn freely without smell, while the latter scarcely burn at all, but simply fuse and frizzle up, give off an unpleasant smell, and leave behind a dark-brown or black ash. These two types of fibres can also be easily

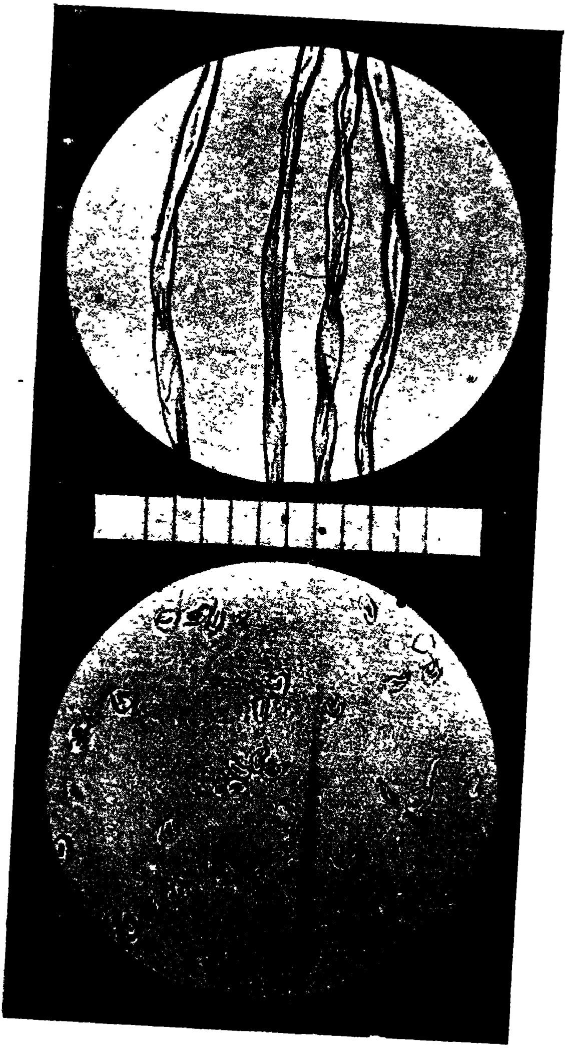


FIG. 7.

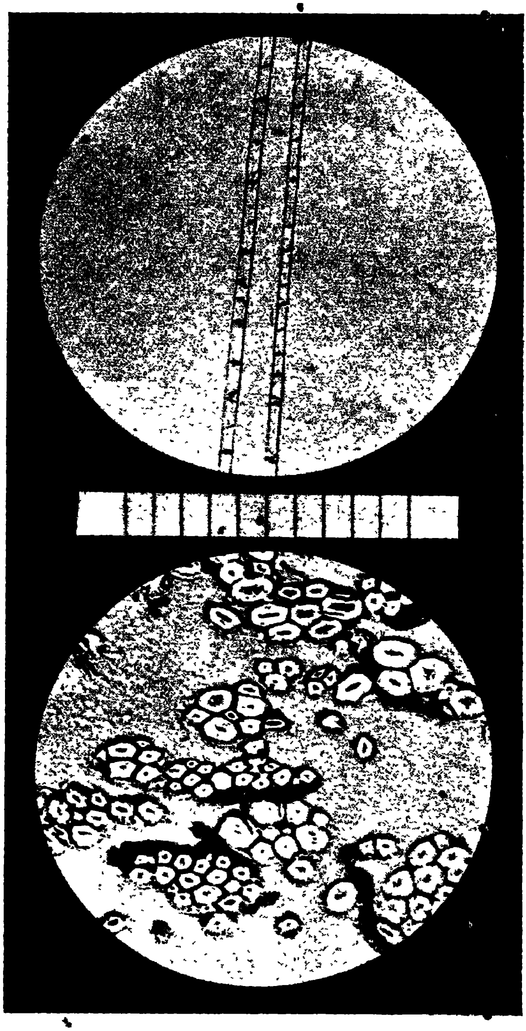


FIG. 8.

distinguished by means of acids and alkalis. Vegetable fibres are soluble in the former and insoluble in the latter, whereas the animal fibres are soluble in alkalis and scarcely affected by the acids.

When a yarn consists of one kind of fibre only, the microscope is perhaps the most reliable test. It is quite common to find wool and cotton mixed in the same yarn (in such cases the relative quantities of each may be obtained by treating the yarn with either acid or alkali). The difference in the length, and in the nature of cotton and flax fibres, prohibits a similar mixture. The fibres of flax and jute are more suited for such combinations; still it is very rare to find a yarn which is composed of these two fibres. When such mixtures do obtain, it is quite clear that the exact proportion of each fibre can be obtained, if at all, only by some chemical test; for the microscope, although capable of showing the difference in the fibres, is incapable of doing more.

Linen and cotton yarns can usually be distinguished from each other by ordinary observation, chiefly on account of the difference in the length of the two fibres. Cotton is short and wavy, varying in length from about ½in. to 2in.; while flax varies in length from 6in. to 36in. in the fibrous condition, being, however, considerably reduced in length when spun. If, therefore, a thread of unknown material be untwisted, and a number of fibres removed, the length of the latter will afford some clue to the material; if cotton, no length will exceed 2in., but if lea or flax line yarn, the fibres may be much longer. Flax tow yarns are not so easily distinguished in this manner, for the fibres are much

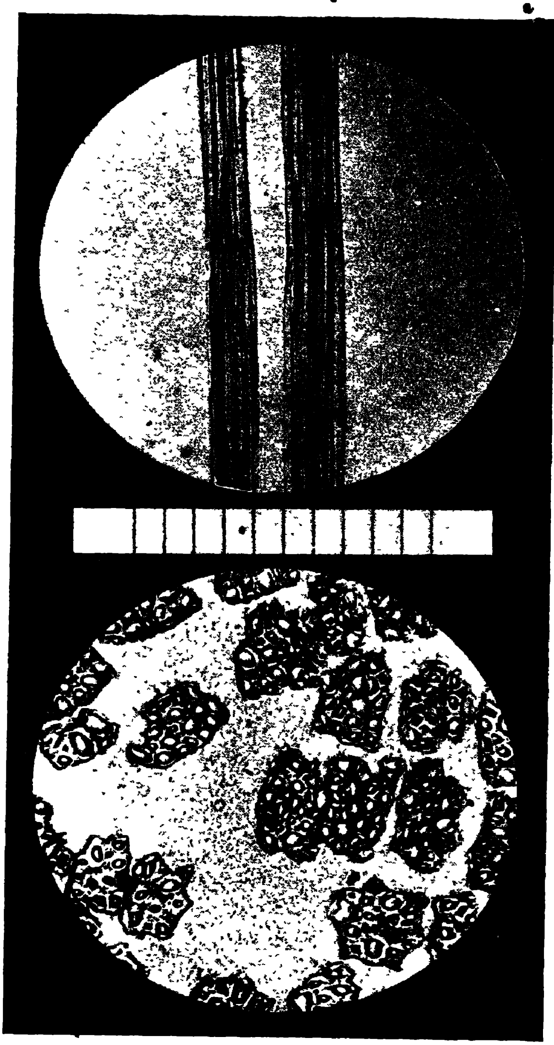


FIG. 9.

shorter than those of flax-line yarns; but here again the high reflective power of the flax as compared with the low reflective power of cotton is sometimes sufficient to determine the fibre. It is here assumed that the cotton has not been mercerised, for yarns subjected to this process have as high, if not a higher, reflective power than flax; if this is suspected the yarns should

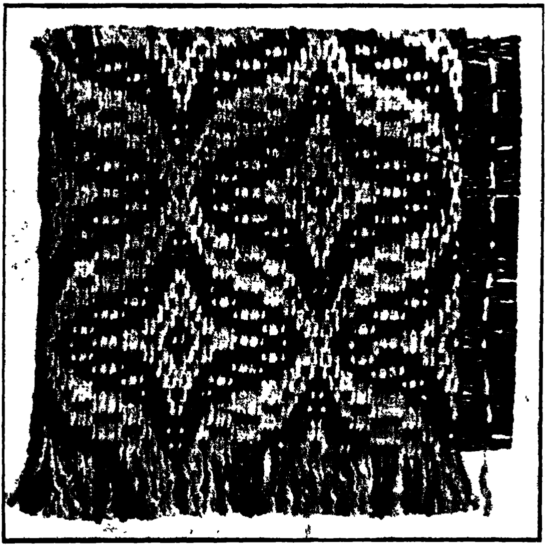


FIG. 10.

be tested more accurately. A very common method of testing a fabric for cotton or flax is to clip two sides and attempt to tear the cloth. If the fabric has not been severely damaged in the bleaching process, the cotton threads will be the more easily torn.

Weave analyses of jute and linen fabrics present no serious difficulties, for the weaves of the greater majority

of such fabrics may be written down by a student of ordinary experience without removing a single thread. Still, when a systematic analysis is imperative, perhaps the best method of procedure is as follows: A small portion of the fabric containing a few repeats (if possible) of the design both by way of the warp and of the weft is cut at the bottom and right-hand side approximately square by a thread, then the threads of warp and weft are removed until about a ¼in. of the interweaving yarn is exposed. The threads of the warp (or of the weft, if more convenient) may then be separated one by one from the main body, as shown in Fig. 10, and their intersections or order of interweaving read off and recorded upon design paper in the usual manner. Before this can be done it is, of course, necessary to first determine which is warp and which weft. This is really the first step in the ordinary analysis, and is sometimes a difficult point to decide. There is, however, a number of guides which help to distinguish between warp and weft, *e.g.*,—

1. The presence of part of the selvage: this should be looked for first.

2. The student should next examine the cloth carefully by looking at and through it for reed marks, or the grouping together of one series of threads in twos, threes, &c., according as the warp has been drawn through the reed. A large number of cloths, and especially the lighter makes, show these marks distinctly, and thus indicate the warp without doubt. In heavily-finished fabrics, however, such as bleached damasks, the reed marks are obliterated; but a close examination of these fabrics will show one series of

threads (the warp) to be perfectly straight, since they have been subjected to a tensile strain both in weaving and in finishing. The weft in such cases is more or less wavy, since the cloth contracts in width both in weaving and in finishing. In addition to this wavy appearance, the weft has a tendency to assume a curved shape, by reason of the tension during the finishing processes.

3. In fabrics of the one-sided type, such as drills, ticks, &c., the bulk of the warp forms the right side of the cloth, and this is easily seen by anyone of experience. A guide in such cases is the fact that the warp threads per inch in general considerably exceed those of the weft. In the finest damasks the picks exceed the threads.

In bleached huckabacks the floats in the warp are straighter and more uniform than those made by the weft. The same remark applies to all cloths which contain long floats in both directions.

4. In all fabrics which have been finished in the loom condition a touch of iodine in solution will at once indicate if the warp has been starched or dressed, by causing it to turn bluish-black or brown. It is obvious that such a test is not applicable to goods which have been bleached, nor to those which have been starched previous to finishing. In the first case the bleaching removes the starch obtained in the dressing process, while in the second case the starch covers warp and weft alike.

5. If the threads of one set are two-fold, and the other set single yarn, the former is usually the warp, although not invariably.

6. The fact that the warp threads are generally twisted harder than the weft is also considered a means of discriminating between them in a piece of cloth. Twist, however, varies with the count and quality of the yarn, with the method of warp preparation, and also according to the effect desired; it is, therefore, not a very reliable test.

7. The direction of the twist in some yarns determines which is warp and which weft; but in jute and linen yarns this is valueless, since both warp and weft are twisted in the same direction.

8. In fabrics of the double-warp order, or those in which two threads of warp are drawn through one heddle or mail of the harness, the warp is, of course, self-evident.

9. A broken pattern usually indicates the weft.

10. Wrong drafts indicate the warp.

11. Cracks in the cloth, termed "gaws," "jesps," "shires," &c., are usually in the way of the weft.

12. Stripes in one direction only are usually in the warp; but this is not a safe guide, for many fabrics are woven with the stripes in the weft. For crashes, plain ticks, &c., the guide is safe.

After having successfully determined the warp and the weft ways of the fabric, it is better for the analyst to draw a line on the fabric in the direction of the warp to prevent further doubt. If necessary, he should then proceed to analyse for the weave of the cloth, and to record it as already described. Then with the aid of scissors and a clearly-marked measure he should cut

out a square of the fabric, each side of which is exactly 3in., taking care that his cutting is exactly by a thread both ways. This square should then be weighed accurately in grains, its weight recorded, and further calculated in ounces per square yard, or yard per given width, as may be thought desirable. A square yard is recommended for the purpose of comparison. Warp threads must now be separated from weft threads, the number of each carefully taken, the total of each set weighed accurately, and these facts recorded. In the separation of the warp from the weft a small loss in weight will be observed; the difference between the combined weight of the warp and weft and the weight of the cloth should be added in about equal proportions to the weights of the warp and the weft, unless it is clearly seen that one set loses much more than the other. The next step is to measure accurately in millimetres the average length of the warp and weft threads when these are stretched to their extreme length. These lengths should always be taken on the full side, and especially in the case of linen, since it is nearly impossible to straighten out such threads to their original length when once they have been interwoven in cloth.

From the facts now obtained it is possible to calculate the sett of the fabric and the counts of the yarn in the following manner:—

As a specimen case, let us take a plain brown linen fabric in which the warp is easily distinguished by the reed marks. The square of cloth with 3in. sides, or 9 sq. in., weighs 20·8 grains.

$$\therefore \frac{20{\cdot}8 \text{ grains} \times 1{,}296 \text{ sq. in. in 1 sq. yd.}}{9 \text{ sq. in.} \times 437\frac{1}{2} \text{ grains per ounce}} = 6{\cdot}84\text{ozs. per square yard.}$$

In dissecting it is found that—

112 warp threads weigh	10·45 grains.
And 108 weft threads weigh	10·12 „
Total weight of yarn............	20·57 grains.

Weight of cloth—weight of yarns = loss in dissecting.
∴ 20·8 grains—20·57 grains = 0·23 grain loss.

Adding this waste in approximately equal proportions to warp and weft :—

Warp = 10·45 + 0·12 = 10·57 grains ; and
Weft = 10·12 + 0·11 = 10·23 „

Careful measurement of the warp threads, after extending, is found to be 82mm., and of the weft threads 81mm.

The original length of the cloth is always assumed to have been 3in. × 25·4mm. per inch = 76·2mm., say 76mm.

The calculation for the warp lea count is therefore as follows :—

$$\underbrace{\frac{112 \text{ threads} \times 3\text{in.} \times 82\text{mm.}}{36\text{in. per yard} \times 76\text{mm.}}}_{\text{Length of warp in yards.}} \times \frac{7{,}000 \text{ grains per pound}}{\underset{\text{Weight of warp.}}{10{\cdot}57 \text{ grains}} \times \underset{\text{Yards per lea.}}{300}} = 22{\cdot}23 \text{ leas per pound}$$

Weft.

$$\frac{108 \times 3\text{in.} \times 81\text{mm.}}{36\text{in.} \times 76\text{mm.}} \times \frac{7{,}000}{10{\cdot}23 \times 300} = 21{\cdot}87 \text{ leas per pound.}$$

In the above example the counts appear to be practically the same, viz., 22 leas each ; but a closer examination of the yarns reveals the soft nature and the paler shade of the warp, which leads to the conclusion that it has been boiled and that the weft has not. Allowance for boiling would, of course, decrease the warp count in proportion, and the probability is that the grey

counts of the yarn were 20's lea warp and 22's lea weft. At this stage it is advisable to take the yarns and compare them with other yarns which are known to be 20's and 22's respectively.

Further examples will be given, which will show how this bleaching allowance should be treated. The picks per inch in the loom should be slightly in excess of those in the cloth, to allow for the "draw" in finishing. It is impossible to determine this allowance accurately, since the rough length of the cloth is not known; but for cloth of this character an allowance of from 2 to 4 per cent. is usually enough.

$$\therefore \underset{\text{per inch.}}{\overset{\text{Threads}}{\frac{108}{3}}} \times \underset{\text{cent.}}{\overset{\text{Per}}{\frac{103}{100}}} = 37 \text{ picks per inch in loom,}$$

or $$37 \text{ picks} \times \frac{37}{200} = 6\cdot85 \text{ picks per glass.}$$

If 7 picks per glass were given, it would equal—

$$7 \times \frac{200}{37} = 38 \text{ picks per inch nearly.}$$

This is one of the faults of using so small a basis of counting as $\frac{37}{200}$ of 1in. In the coarser fabrics it would be much better to adopt 1in. as the basis of counting, and it is strongly recommended that all counting of threads when "glassing" a fabric should be done on the largest available measure, because the tendency to error is thus reduced to a minimum.

The calculation for the sett of the reed is as follows:—

$$\frac{\underset{\text{Threads per in. in reed.}}{112 \text{ threads}} \times \overset{\text{Weft contraction.}}{76\text{mm.}}}{38 \times 1\text{mm.}} \times \frac{40\text{in. reed basis}}{2 \text{ thds. per split}} = 700 \text{ reed on 40in. scale.}$$

The above facts should be collected in tabular form as under :—

1. Description and weave of fabric........Plain brown linen.
2. Weight of square of 3in. side (9 sq. in.) ......$=20{\cdot}8$ grains.
3. ,, per square yard $\frac{20{\cdot}8 \times 1{,}296}{9 \times 437\frac{1}{2}}$ ....$=6{\cdot}84$oz.
4. Total number of warp threads in 3in. ......$=112$
5. ,, ,, weft ,, ,, ...$=108$
6. Total weight of warp $10{\cdot}45+0{\cdot}12$ ....$=10{\cdot}57$ grains.
7. ,, ,, weft $10{\cdot}12+0{\cdot}11$ ....$=10{\cdot}23$,,
8. Threads per inch in warp $\frac{112}{3}$ ....$=37\frac{1}{3}$ per inch.
9. ,, ,, weft $\frac{108}{3}$ ....$=36$,,
10. Length of warp threads when stretched ....$=82$mm.
11. ,, weft ,, ,, ...$=81$,,
12. Count of warp $\frac{112 \times 3 \times 82 \times 7{,}000}{36 \times 76 \times 10{\cdot}57 \times 300}$ ....$=22{\cdot}23$ leas.
13. ,, weft $\frac{108 \times 3 \times 81 \times 7{,}000}{36 \times 76 \times 10{\cdot}23 \times 300}$ ....$=21{\cdot}87$,,
14. Sett of reed $\frac{112 \times 76 \times 40\text{in.}}{3 \times 81 \times 2}$ ....$=7^{00}$ reed.
15. Width in reed for 36in. cloth $\frac{36 \times 81}{76}$ ....$=38{\cdot}4$in. (probably 39in.)
16. Picks per inch in loom ....$=37$

Example LIX.—Analysis of a jute hessian in the rough or unfinished condition, commonly termed a rough hessian. On the right-hand side of Fig. 11 (which is produced from a photograph of the cloth) appear two warp threads; the one nearer the cloth represents the wavy or corrugated form which the yarn assumes in the cloth, while the thread on the extreme

right represents the actual length of the yarn when stretched. The two lengths of yarn at the bottom of the figure represent similar conditions of the weft. A glance through this cloth at once shows the reed marks, and these indicate the warp way of the fabric. The cloth is undyed, and the warp undressed.

PARTICULARS.

1. Description and weave of fabric ....Rough hessian; plain weave.
2. Weight of square of 3in. side (9 sq. in.) ...... =42·83 grains.
3. „ per yard 40in wide

$$\frac{42{\cdot}83 \times 36 \times 40}{9 \text{ sq. in.} \times 437\tfrac{1}{2} \text{ grains}} = 15{\cdot}66\text{oz.}$$

4. Total threads of warp in 3in. .... =43
5. „ „ weft „ .... =49
6. Total weight of warp 19·66+0·34 grains .. =20·00 grains.
7. „ „ weft 22·48+0·35 „ ... =22·83 „
8. Threads per inch of warp.................. $=14\frac{1}{3}$
9. „ „ weft .... $=16\frac{1}{3}$
10. Length of warp threads...... .... =86mm.
11. „ weft „ .... =80 „
12. Count of warp $\dfrac{20 \text{ grains} \times 36 \times 76 \times 14{,}400}{7{,}000 \text{ grains} \times 3 \times 86 \times 43}$ .. =10·15lbs. per spyndle.
13. „ weft $\dfrac{22{\cdot}83 \text{ grains} \times 36 \times 76 \times 14{,}400}{7{,}000 \text{ grains} \times 3 \times 80 \times 49}$ =10·93 „
14. Sett of reed $\dfrac{43 \times 76 \times 37}{3 \times 80 \times 40}$ .... =12·6 porter.
15. Width in reed for 40in. cloth 40in. $\times \dfrac{80}{76}$ .... =42·10in.(probably $42\frac{1}{2}$in.)
16. Picks per inch in loom .... $=16\frac{1}{3}$

The cloth has probably been woven in a 13-porter reed with 10lbs. warp, and 16 shots per inch of 11lbs. weft. Since the cloth is unfinished, the number of picks per inch in the loom and in the cloth is practically the same; the slight decrease of picks in the loom is the result of the higher tension while the cloth is being woven.

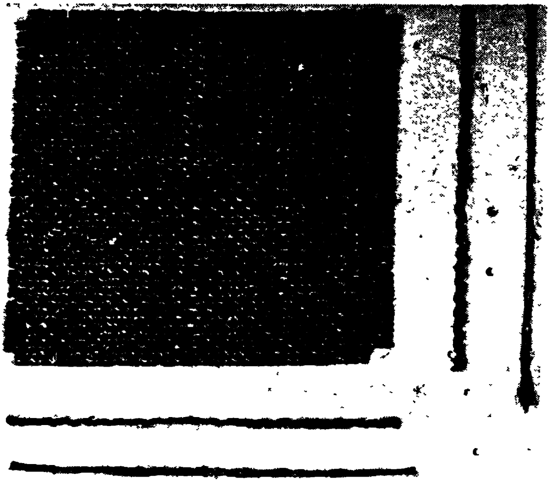


FIG. 11.

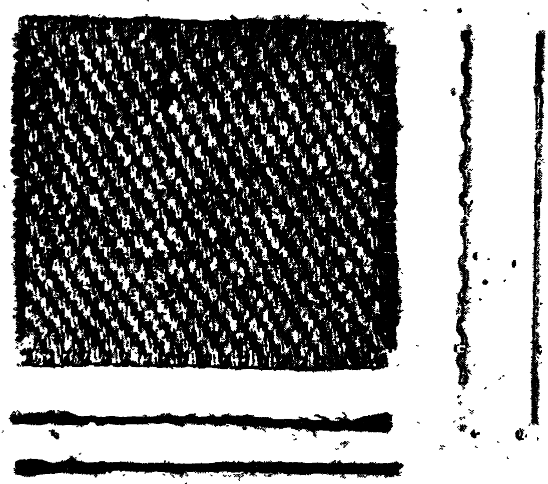


FIG. 12.

Example LX.—Analysis of a 3-leaf D.W. twilled jute sacking. Fig. 12 shows a photographical reproduction of the cloth, also of two threads and two picks. The warp threads again appear on the right in the wavy and distended conditions, while a similar disposition of the weft is shown at the bottom of the figure. Being a double-warp fabric the warp way of the cloth is obvious, whilst the absence of a stain on the application of iodine indicates that the warp has not been dressed.

PARTICULARS.

1. Description and weave of fabric ...... D.W. twilled sacking 3-leaf twill $\frac{2}{1}$.
2. Weight of square of 3in. side (9sq. in.) ...... = 75·35 grains.
3. „ per yard 28in. wide $\frac{75{\cdot}35 \times 28\text{in.} \times 36\text{in.}}{9\text{ sq. in.} \times 437{\cdot}5} = 19.29\text{oz.}$
4. Total threads of warp in 3in. .... = 117
5. „ „ weft „ .... = 33
6. Total weight of warp 40·30 + 0·35 grains .... = 40·65 grains.
7. „ „ weft 34·40 + 0·30 „ .... = 34·70 „
8. Threads per inch of warp................ = 39
9. „ „ weft .... = 11
10. Length of warp threads .... = 84mm.
11. „ weft „ .... = 78 „
12. Count of warp $\frac{40{\cdot}65\text{ grains} \times 36\text{in.} \times 76 \times 14{,}400}{7{,}000\text{ grains} \times 3\text{in.} \times 84 \times 117\text{ threads}} = 7{\cdot}76$lbs. per spyndle.
13. Count of weft $\frac{34{\cdot}70\text{ grains} \times 36\text{in.} \times 76 \times 14{,}400}{7{,}000\text{ grains} \times 3\text{in.} \times 78 \times 33\text{ threads}} = 25{\cdot}29$lbs. per spyndle.
14. Sett of reed $\frac{117}{3\text{in.} \times 6\text{ threads per split}} \times \frac{76 \times 37}{78 \times 20} = 11{\cdot}72$ porter.
15. Width in reed for 28in cloth $\frac{28\text{in.} \times 78}{76}$ ...... = 28·74 (probably 29in.)
16. Picks in loom $11 \times \frac{104}{100} \times 3$ .... = 34·32 in 3in.

From the above it may be deduced that the cloth was woven in a 12-porter reed, 3 double threads per split of 8lbs. warp, and with 34 to 35 shots per 3in. of 26lbs. weft, the reed width being probably 29in.

Example LXI.—Analysis of a yarn-dyed jute cloth intended for the backs of rugs—usually termed jute rug backing. In this sample (which is shown in the usual way in Fig. 13) several features point out the

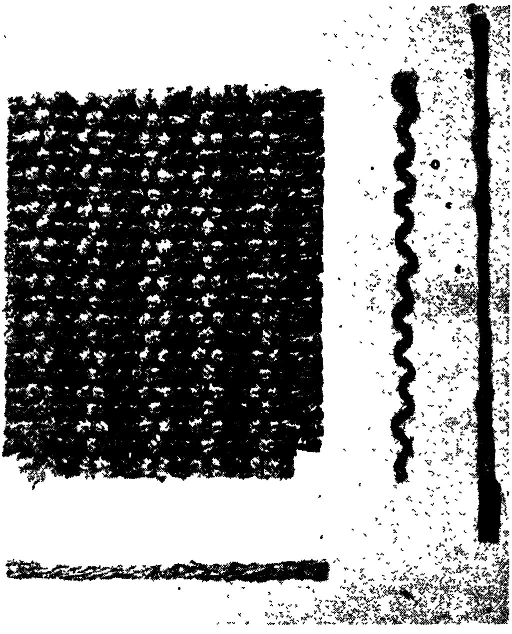


FIG. 13.

warp way of the cloth—*e.g.*, slight reed marks; the warp is in stripes of two colours, each stripe consisting of three threads, which are drawn through one split of the reed. If such stripes were in the way of the weft, it would be necessary to weave the cloth in a loom with boxes at both ends and a pick-at-will arrangement The warp is 3-fold, and the weft 6-fold yarn.

PARTICULARS.

1. Description and weave of fabric .... Jute rug backing plain weave.
2. Weight of square of 3in. side (9 sq. in.)...... = 132·9 grains.
3. „ per square yard $\frac{132\cdot9 \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\cdot5}$ = 43·74oz.
4. Total threads of warp in 3in. .... = 44
5. „ „ weft „ .... = 23
6. Total weight of warp 68·98 + 0·00 grains .... = 68·98 grains.
7. „ „ weft 63·88 + 0·04 „ .... = 63·92 „
8. Threads per inch of warp 44/3in. .... = 14⅔ per inch.
9. „ „ weft 23/3in. .... = 7⅔ „
10. Length of warp threads .... = 103mm.
11. „ weft „ .... = 77 „
12. Count of warp $\frac{68\cdot98 \times 36\text{in.} \times 76 \times 14{,}400}{7{,}000 \times 3\text{in.} \times 103 \times 44}$ .... = 28·56lbs. per spyndle.
13. Count of weft $\frac{63\cdot92 \times 36\text{in.} \times 76 \times 14{,}400}{7{,}000 \times 3\text{in.} \times 77 \times 23}$ .... = 67·72lbs. per spyndle.
14. Sett of reed $\frac{44 \times 76 \times 37}{3\text{in.} \times 3 \text{ threads} \times 77 \times 20}$ .... = 8·93 porter.
15. Width in reed for 36in. cloth $\frac{36\text{in.} \times 77}{76}$ ...... = 36·5in.
16. Picks in loom $7\frac{2}{3} \times 3$ .... = 23 in 3in.

The cloth has evidently been woven through a 9-porter reed, 3 threads per split; and the weft probably intended to have been 8 shots per inch. The warp $\frac{28\cdot56}{3\text{-fold}} = 9\cdot52$lbs. in the single, and the weft $\frac{67\cdot72}{6\text{-fold}}$ = 11·28lbs. in the single; but since all dyed yarns lose more or less of their weight during dyeing, the original counts have probably been 3-fold 10lbs. warp and 6-fold 12lbs. weft respectively. This would make allowance for a loss of about 5 per cent. in the dyeing of the warp, and 6 per cent. in the dyeing of the weft; these allowances are under rather than over the average for jute yarns.

Example LXII.—Analysis of a twilled flax sheeting (see Fig. 14). The following allowances have been made :—

1st. 5 per cent. for increase in the dressing of the warp.
2nd. 20 per cent. for loss during the bleaching of the warp.
3rd. 15 per cent. for loss during the bleaching of the weft.

The warp way of this cloth is evident even from the illustration, in which the reed marks are plainly visible.

PARTICULARS.

1. Description and weave of fabric ...... Twilled flax sheeting $^{2}_{2}$ serge twill.
2. Weight of square of 3in. side (9 sq. in.) ...... = 20·15 grains.
3. „ per sq. yd. $\frac{20\cdot15 \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\cdot5}$ ...... = 6·63oz.
4. Total threads of warp in 3in. .... = 121
5. „ „ weft „ .... = 121
6. Total weight of warp 11·65 + 0·05 grains .... = 11·70 grains.
7. „ „ weft 8·40 + 0·05 „ .... = 8·45 „
8. Threads per inch of warp.................. = 40⅓
9. „ „ weft .... = 40⅓
10. Length of warp threads.................... = 80mm.
11. „ weft „ .... = 79 „
12. Count of warp $\frac{11\cdot70 \times 36 \times 76 \times 14{,}400 \times 100 \times 100}{7{,}000 \times 3 \times 80 \times 121 \times \underset{\text{Gain in dressing.}}{105} \times \underset{\text{Loss in bleaching.}}{80}} = 2\cdot70\text{lbs.}$
(say 2¾lbs.) per spyndle.
13. Count of weft $\frac{8\cdot45 \times 36 \times 76 \times 14{,}400 \times 100}{7{,}000 \times 3 \times 79 \times 121 \times \underset{\text{Loss in bleaching.}}{75}} = 2\cdot21\text{lbs.}$
(say 2¼lbs) per spyndle.
14. Sett of reed $\frac{121 \times 76 \times 37}{3 \times 79 \times 40}$ .. = 35·89 porter (say 36 porter).
15. Width in reed for 36in. cloth $\frac{36\text{in.} \times 79}{76}$ .. = 37·42 (say 38in.).
16. Picks per inch in loom .... = say 41 per in

There is very little finish on this cloth, therefore very little draw in finishing.

Example LXIII.—Analysis of a 3-leaf twill blue-and-white ticking as shown in Fig. 15, making the following allowances :—

5 % for loss in dyeing the two-fold cotton warp.
15 „ bleaching the flax lea warp.
20 „ „ „ weft.

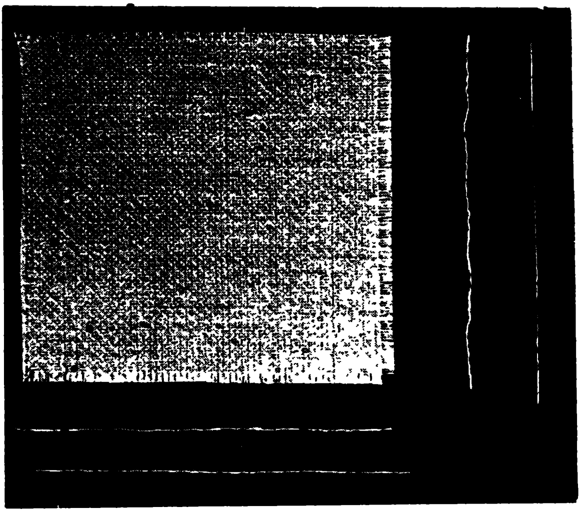


FIG. 14.

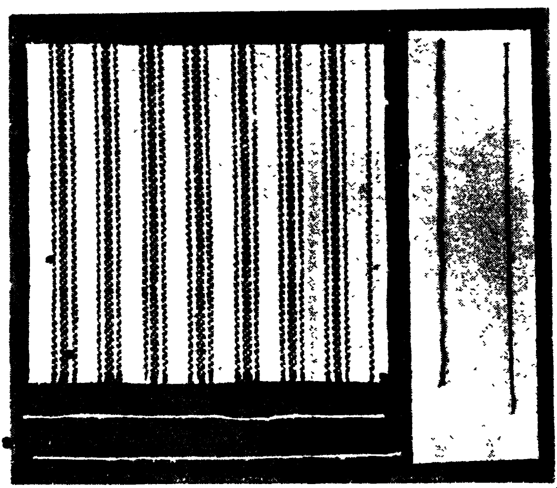


FIG. 15.

The warp is, of course, clearly indicated by the stripes in the fabric, and the threads are arranged as under :—

White	11	2	2	= 15 white per repeat.
Blue	2	4	4	= 10 blue ,,

PARTICULARS.

1. Description and weave of fabric ....Blue and white ticking 3-leaf twill $\frac{2}{1}$ straight draft.
2. Weight of square of 3in. side (9sq. in.) ...... = 26·37 grains.
3. ,, per sq. yd. $\frac{26\cdot37 \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\frac{1}{2}}$ .... = 8·68oz.
4. Total threads of warp in 3in. .... = 180
5. ,, ,, weft ,, ... = 142
6. Threads per inch of warp.................. = 60
7. ,, ,, weft .... = $47\frac{1}{3}$
8. Length of warp thds., both lea and cot. yarns = 85mm.
9. ,, weft threads .... = 79 ,,
10. Total weight of warp—
    62 threads blue cotton 4·48 + 0·02 ...... = 4·50 grains.
    118 ,, lea warp 10·59 + 0·08 .... = 10·67 ,,
11. Total weight of weft 11·10 + 0·10 .... = 11·20 ,,
12. Count of cotton warp—
    $$\frac{62 \text{ threads} \times 3\text{in.} \times 85 \times 7{,}000 \times \overset{\text{Loss in dyeing.}}{95}}{840 \text{ yds.} \times 36\text{in.} \times 76 \times 4\cdot5 \times 100} \text{ .... } = 10\cdot1$$ (say 2/20's cotton).
13. Count of lea warp—
    $$\frac{118 \text{ threads} \times 3\text{in.} \times 85 \times 7{,}000 \times 85}{300 \text{ yds.} \times 36\text{in.} \times 76 \times 10\cdot67 \times \underset{\text{Loss in bleaching.}}{100}} \text{ ...... } = 20\cdot4$$ (say 20 lea).
14. Count of lea weft—
    $$\frac{142 \text{ threads} \times 3\text{in.} \times 79 \times 7{,}000 \times 80}{300 \text{ yds.} \times 36\text{in.} \times 76 \times 11\cdot20 \times \underset{\text{Loss in bleaching.}}{100}} \text{ .... } = 20\cdot5$$ (say 20 lea).
15. Reed in porter scale $\frac{180 \times 76 \times 37}{3\text{in.} \times 79 \times 20 \times 3 \text{ threads}} = 35\cdot6$ (say 36 porter reed 3 in split).
16. Reed width for 58in cloth $58 \times \frac{79}{76}$ .... = 60·3in. (say $60\frac{1}{4}$in.)
17. Picks per inch in loom $\frac{142}{3} \times \frac{103}{100}$ .... = 48·75 (say 49 per inch).

Example LXIV.—Analysis of a bleached linen damask, as shown in Fig. 16, making an allowance of 28 per cent. for bleaching from the grey yarn to the

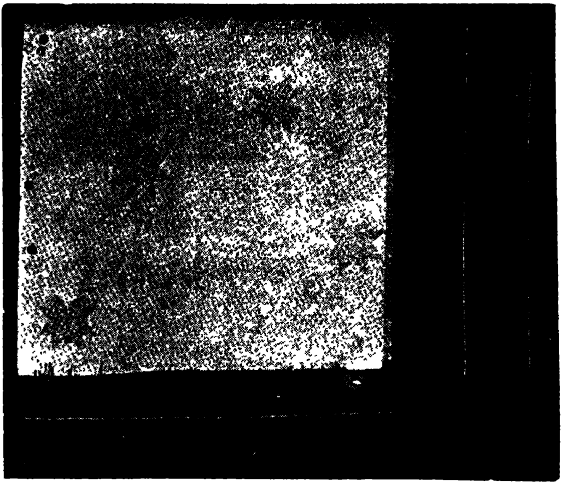


FIG. 16.

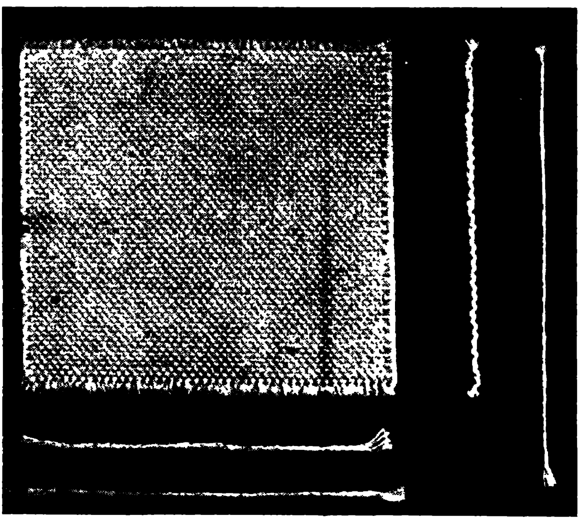


FIG. 17.

finished cloth. This allowance may appear high, but it is within bounds, for the bleaching loss of such fabrics varies from 25 to 30 per cent. In exceptional cases the latter figure is exceeded. The warp is here distinguished by its straight or rigid appearance, as well as by the difference in contraction in the two sets of threads.

PARTICULARS.

1. Description and weave of cloth...... Bleached damask 5-thread sateen weave, ground and figure.
2. Weight of square of 3in side (9 sq. in.)...... = 14·55 grains.
3. ,, per sq. yd. $\frac{14\cdot55 \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\frac{1}{2}}$ .... = 4·79oz.
4. Total threads of warp .... = 178
5. ,, ,, weft .... = 163
6. Threads per inch of warp .... = $59\frac{1}{3}$
7. ,, ,, weft .... = $54\frac{1}{3}$
8. Length of warp threads .... = 77mm.
9. ,, weft ,, ... = 82 ,,
10. Weight of warp 7·48 grains + 0·03 grains ... = 7·51 grains.
11. ,, weft 7·01 grains + 0·03 grains.... = 7·04 ,,
12. Count of warp $\frac{178 \text{ thds.} \times 3\text{in.} \times 77 \times 7{,}000 \times 72}{300 \text{ yds.} \times 36\text{in.} \times 76 \times 7\cdot51 \times \underbrace{100}_{\text{Loss in bleaching.}}} = 33\cdot62$ leas per pound.
13. Count of weft $\frac{163 \text{ thds.} \times 3\text{in.} \times 82 \times 7{,}000 \times 72}{300 \text{ yds.} \times 36\text{in.} \times 76 \times 7\cdot04 \times \underbrace{100}_{\text{Loss in bleaching.}}} = 34\cdot97$ leas per pound.
14. Sett of reed in porter scale $\frac{178 \times 76 \times 37}{3\text{in.} \times 82 \times 40}$ .. = 50·87 porter.
15. Width in reed for 72in. finished cloth $72 \times \frac{82}{76} = 77\cdot68$ (say 77in.)
16. Picks per inch in loom $\frac{163 \times 103}{3 \times 100}$ .... = 56 nearly.

As a matter of fact, the above cloth was woven through a 50 porter reed, 2 threads per split, with 32's lea warp and 35's lea weft.

Example LXV.—Analysis of a single warp cotton

canvas, made from 6-fold warp and 9-fold weft, each losing say 5 per cent. in bleaching. Fig. 17 illustrates the fabric, which is interesting on account of the excessive contraction of the warp as compared with that of the weft. This is a feature which is characteristic of all heavy canvases (flax and cotton), and which serves to distinguish the warp from the weft.

PARTICULARS.

1. Description and weave of cloth...... Bleached cotton canvas, plain weave.
2. Weight of square of 3in. side (9 sq. in.)...... =67·52 grains.
3. ,, per square yard $\frac{67 \cdot 52 \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\frac{1}{2}}$ =22·22oz.
4. Total threads of warp .... =93
5. ,, ,, weft .... =73
6. Threads per inch of warp .... =31
7. ,, ,, weft .... =24⅓
8. Length of warp threads .... =98mm.
9. ,, weft ,, ... =80 ,,
10. Weight of warp 34·95 grains + 0·25 grains .. =35·20 grains.
11. ,, weft 32·05 ,, + 0·27 ,, .. =32·32 ,,
12. Count of warp—

$$\frac{93 \text{ thrds.} \times 3\text{in.} \times 98 \times 7{,}000 \times 95}{840 \text{yds.} \times 36\text{in.} \times 76 \times 35 \cdot 2 \times 100} = 2 \cdot 25 \times 6 \text{ fold} = 13 \cdot 50 \text{ (say 6/14's).}$$

Loss in bleaching.

13. Count of weft—

$$\frac{73 \text{ threads} \times 3\text{in.} \times 80 \times 7{,}000 \times 95}{840 \text{yds.} \times 36\text{in.} \times 76 \times 32 \cdot 32 \times 100} = 1 \cdot 57 \times 9 \text{ fold} = 14 \cdot 13 \text{ (say 9/14's).}$$

Loss in bleaching.

14. Sett of reed in splits per inch $\frac{31 \times 76}{2 \times 80}$ = 14·7 (say 15 splits per in., 2 thds. per split).
15. Width in reed for 24in. cloth $24 \times \frac{80}{76}$ .... =25¼in.
16. Picks per inch in loom = probably 24 per inch, since the cloth is only lightly finished.

Example LXVI.—Analysis of a fancy cotton skirting as represented photographically in Fig. 18. Unlike

the majority of striped fabrics, the stripes in this cloth, as well as in some well-known types of heavy shirting, are produced by the weft. There is in general some peculiar feature which enables one to determine the warp way of such fabrics; but in a few cases this matter is difficult to decide. In this particular instance the warp is indicated by the fact that it is 3-fold, while the

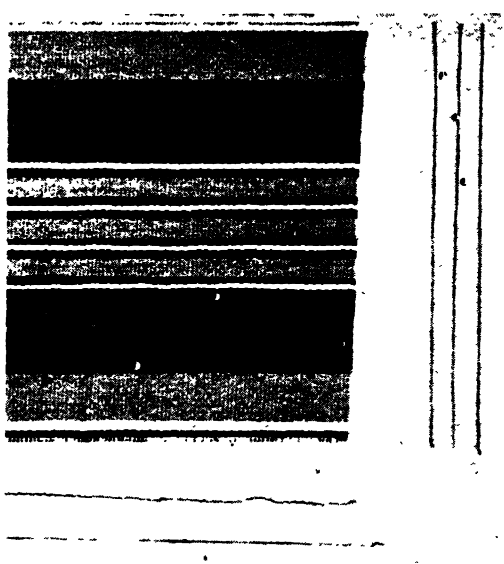


FIG. 18.

weft is a soft single yarn, quite unsuitable for the strain to which the warp is subjected. The full weft pattern contains only six colours, but due to the order in which these are arranged, a 12-chamber revolving box is necessary, unless the changing mechanism is made to skip two or more boxes.

PARTICULARS.

1. Description and weave of fabric....Fancy striped cotton skirting, plain weave.
2. Weight of square of 3in. side (9 sq. in.) ...... =21 grains.
3. ,, per square yard $\frac{21\text{grs.} \times 36\text{in.} \times 36\text{in.}}{9 \text{ sq. in.} \times 437\frac{1}{2}} = 6{\cdot}91\text{oz.}$
4. Total threads of warp .... =104
5. ,, ,, weft .... =463
6. Threads per inch of warp.................. =$34\frac{2}{3}$
7. ,, ,, weft .... =$154\frac{1}{3}$
8. Length of warp threads .... =78mm.
9. ,, weft .... =84 ,,
10. Weight of warp 3·85 grains+0·05 grains.... =3·90 grains.
11. ,, weft 17·02 ,, +0·08 ,, ... =17·10 ,,
12. Count of warp $\frac{104 \text{ threads} \times 3\text{in.} \times 78 \times 7{,}000}{840 \text{ yds.} \times 36\text{in.} \times 76 \times 3{\cdot}9} = 19\text{'s}$ (say 3/60's cotton).
13. Count of weft—
$$\frac{463 \text{ threads} \times 3\text{in.} \times 84 \times 7{,}000 \times 95}{840 \text{ yds.} \times 36\text{in.} \times 76 \times 17{\cdot}10 \times \underset{\text{Loss in dyeing.}}{100}} \text{........} = 19{\cdot}74 \text{ (say 20's).}$$
14. Sett of reed $\frac{104 \text{ threads} \times 76}{3 \times 2 \text{ threads} \times 84} = 15{\cdot}68$ (say 16 splits per inch, 2 threads per split).
15. Width in reed for 36in. cloth $36\text{in.} \times \frac{84}{76}$ .. =39·8 (say 40in.)
16. Picks per inch in loom .... =156, or 39 per $\frac{1}{4}$in.)

No allowance has been made for dyeing in the warp calculation, it being assumed that such loss would be counterbalanced by the contraction in length due to twisting.

CHAPTER X.

YARN DIAMETERS AND THEIR STRUCTURAL VALUES.

THE analysis of jute and linen fabrics, or, indeed, of any similar cloth, should present but few difficulties, if some method similar to those which have been indicated is adopted. All the elements of the cloth are before the analyst in a more or less concrete form, and he should be able, provided a reasonable amount of care is exercised, to obtain results which are practically correct.

The aim of analysis is, of course, to enable one to supply the particulars necessary for the reproduction of the fabric; but, in cases where the weight and set of the cloth are supplied, a detailed analysis is unnecessary, the desired particulars being obtained by a simple experimental calculation. At other times, however, no such guide would be given, but merely a request made for a similar fabric in perhaps a finer or a coarser set. In such a case, an analysis of the fabric is undoubtedly valuable as a guide to its general structure; but the problem before the manufacturer is then more one of synthesis than of analysis. We are aware that it is most unusual in practice to find any attention given to mathematical rules for cloth structure, experiment being generally adopted in preference to calculation. We do not suggest that experiment should be discarded entirely—

in fact, it cannot be dispensed with—but we feel confident that if more attention were given to those theoretical rules of cloth structure which are already fairly well known, much useless and wasteful experimenting would be avoided.

A little thought will show that the chief items affecting cloth structure from a theoretical point of view are: Firstly, the thickness of the yarns employed, and the intersections which they form in producing the cloth; secondly, but none the less important, the facts that yarn is not incompressible, and that in weaving it is deflected out of a straight line.

Regarding the thickness of the yarns employed, it has been shown in an earlier portion of this work that the count of any yarn is determined by the relation of its length to its weight, a definition in which only one dimension of its volume is considered. Now, while yarns are by no means uniform, they yet possess a more or less circular form, and a cross section of any thread at any point, therefore, resembles a circle with its dimensions of area and diameter. Now the sectional area of a cylindrical body multiplied by its length gives its cubical contents; therefore, since

$$d^2 \times \frac{\pi}{4} = \text{area of a circle},$$

$$d^2 \times \frac{\pi}{4} \times l = \text{cubical contents of any thread},$$

where d is the average diameter and l the length of the yarn. This is true no matter of what fibre the yarn is composed. Now, let us suppose that this volume $d^2 \times \frac{\pi}{4} \times l$ weighs 1lb., and let us take a second volume of yarn whose length is precisely the same as the first,

but whose weight is exactly double, *i.e.*, 2lbs. The diameter of the latter yarn will naturally be greater and the cubical contents or volume of such yarn may be represented by $D^2 \times \frac{\pi}{4} \times l$. The following relation then holds between the two yarns :—

$$\text{(A)} \quad \frac{\text{1lb. yarn}}{\text{2lbs. yarn}} = \frac{d^2 \times \frac{\pi}{4} \times l}{D^2 \times \frac{\pi}{4} \times l};$$

$$\text{or 1lb. : 2lbs.} = d^2 : D^2$$

—*i.e.*, the weights of any two yarns vary directly as the squares of their diameters (if their densities are assumed to be equal), and, conversely, the diameters of any two yarns vary directly as the square roots of their weights. This is, of course, true of all yarns, and may be applied directly to those systems of counting where the length is fixed and the weight varies, since for such yarns the weight and the count are synonymous terms. For those yarns, however, which are numbered according to a constant weight and a varying length, an alteration is necessary. Thus the lea counts of 1lb. and of 2lbs. yarn (jute and flax system) are 48 lea and 24 lea respectively, *i.e.*, the lighter yarn has the higher number and the smaller diameter. Therefore, for lea and cotton yarns, and for all others of analogous systems of counting, the counts are inversely proportional to the squares of their diameters. Thus—

$$\text{(B)} \quad 48\text{'s} : 24\text{'s} = D^2 : d^2.$$

The above are the most convenient expressions to use, unless the numbers representing the weights or the counts of both yarns are complete squares. In

such cases it is easier to extract the square root from each term. The whole may be summed up as follows :—

Let W and w = the heavier and the lighter weights of yarn,

C and c = the higher and the lower counts of yarn,

D and d = the greater and the lesser diameter of yarn.

Then (system A) $w : W = d^2 : D^2$,

$$\text{or, } \sqrt{w} : \sqrt{W} = d : D,$$

where the length of the yarn is fixed, and the weight varies as in the flax and the jute systems.

For (system B),

$$c : C = d^2 : D^2,$$

$$\text{or } \sqrt{c} : \sqrt{C} = d : D,$$

where the weight is fixed, and the length varies as in cotton, woollen, and worsted, and in spun silk yarns.

The above, however, simply shows the relation between the various counts and their diameters; it gives us no idea of the actual values of the latter. The relative diameters are nevertheless quite sufficient for the purpose of making several simple but generally hypothetical changes in cloth structure when certain data are given. For example, it may be found that a 9lbs. jute warp gives a satisfactory plain cloth in a 12-porter reed, and the question asked : What reed should be used with 16lbs. warp to give a cloth similar in structure? This phrase, "similar in structure," demands some explanation, although it is somewhat difficult to define. For cases, however, where the weaves are to remain the same it may be defined as "the preservation of the spacing of the warp and the weft threads in exact proportion to their diameters." In the example

suggested, the sett of the warp is 12-porter $\times \frac{40}{37} =$ approximately 13 threads per inch of 9lbs. yarn; therefore the centres of each pair of contiguous warp threads are $\frac{1}{13}$in. apart. But, since a 16lbs. thread is heavier and has a greater diameter than a 9lbs. thread, the distance between these centres must be greater if a similar structure is to be preserved. The correct distance apart for a 16lbs. yarn will be :—

$$9 : 16 = (\tfrac{1}{13})^2 : x^2 ;$$

$$\text{or, } 3 : 4 = \tfrac{1}{13} : x.$$

$$3x = \frac{4}{13}, \text{ or } x = \frac{4}{3 \times 13} = \frac{1}{9{\cdot}75}\text{in., or nearly } \tfrac{1}{10}\text{in. apart;}$$

hence 9·75 threads per inch $\times \frac{37}{40}$ = 9-porter reed required.

It is unnecessary, however, to calculate the exact number of threads per inch, for $\frac{1}{13} : x$ is simply a ratio, and ratios are unaltered when multiplied or divided by any number; consequently we may use the porter or any other method of stating the sett of the reed directly. In the above example the threads were spaced apart $\frac{1}{12}$ of $\frac{37}{40}$in.

$$\therefore 9 : 16 = (\tfrac{1}{12})^2 : x^2,$$

$$\text{or } 3 : 4 = \tfrac{1}{12} : x.$$

$$3\,x = \tfrac{4}{12}, \text{ or } x = \tfrac{4}{36} = \tfrac{1}{9}$$

—*i.e.*, the centres of the adjacent threads of the new cloth should be $\frac{1}{9}$ of $\frac{37}{40}$in. apart; therefore the porter of the required reed is 9. The answer in the above expression—*i.e.*, $\frac{1}{9}$—is the reciprocal of the porter; if, therefore, we change x^2 into its reciprocal—*i.e.*, $\dfrac{1}{x^2}$

—we shall obtain the porter direct. Thus:

$$\frac{9}{16} = \frac{\left(\frac{1}{12}\right)^2}{\frac{1}{x^2}}, \text{ or } \frac{9}{16} = \frac{x^2}{12}$$

$$\text{—}i.e.,\ 16 : 9 = 12^2 : x^2,$$
$$4 : 3 = 12 : x;$$

whence x = 9-porter, as before.

This is the usual and best form of stating the relation. We therefore have the following rule for such changes for system A.

RULE XXVII.—The count (pounds per spyndle) of the yarn in the required cloth is to the count in the given cloth as the given reed or sett squared is to the required reed or sett squared.

RULE XXVIII.—Similarly for system B we have: The lea count in the given cloth is to the lea count in the required cloth as the given reed or sett squared is to the required reed or sett squared.

For example, 20's lea warp is found to give a satisfactory plain cloth in a 700's reed, 40in. scale, and it is required to find a suitable count to give a cloth of similar structure, but for a 10°° reed

$$700^2 : 1{,}000^2 = 20 : x.$$

$$\therefore x = \frac{10 \times 10 \times 20}{7 \times 7}$$

$$= 41 \text{ nearly, or say, 40's lea warp.}$$

Questions affecting the weft may be treated in exactly the same manner.

We think it is necessary at this stage to draw attention to the fact that while the above changes nominally preserve the structure of the fabric, the weight of the cloth is materially altered, being made lighter or heavier

according as the cloth becomes finer or coarser. In the first example the relative weights of the cloths are :—

9lbs. × 12-porter : 16lbs. × 9-porter = 108 : 144, being an increase of $\frac{36}{108}$, or $\frac{1}{3}$ in weight, whilst in the second example the relative weights are approximately :

$$\frac{700}{20 \text{ lea}} : \frac{1{,}000}{40 \text{ lea}} = 35 : 25,$$

being a decrease of $\frac{10}{35}$, or $\frac{2}{7}$ in weight.

This latter portion brings us naturally to the next simple change, viz., that of increasing or decreasing the weight of the fabric without change of weave, or alteration of the balance or structure of the cloth. In this connection it may be affirmed that only one maximum and so-called perfectly balanced plain cloth can be made from a given yarn, and that, were it decided to effect any desired increase in weight by a proportionate increase in the weight of the yarns alone, the attempts would most probably end in failure, for the increased diameter of the warp and the weft would resist the insertion of the requisite number of weft threads per inch. From the above two examples it will be seen that the ratio of the weights of the two cloths, which is 3 : 4 in the former example, and 5 : 7 in the latter, is directly proportional to the square roots of the weights of the two yarns, and therefore to their diameters, but is inversely proportional to the reed setts. Consequently, if the theoretical structure of the fabric is to be preserved, any increase of weight must be effected by reducing the sett, and by increasing the diameter of the yarn in proportion to the weights of the two fabrics; and, conversely, a decrease in the weight should be effected by increasing the sett, and by reducing the diameter

of the yarn in proportion to the respective weights. Suppose that a 36-porter plain flax sheeting is made from $2\frac{1}{2}$lbs. warp and weft, and weighs 7oz. per square yard, and that it is desired to make one to weigh 9oz. per square yard. The relative weights are 7 to 9. The reed sett should be reduced in these proportions :—

$$\therefore 9 : 7 = 36 : x;$$

whence $x = 28$-porter, and the yarn diameter should be increased in the proportion—

$$7 : 9 = \sqrt{2\tfrac{1}{2}} : \sqrt{x},$$

$$\text{or } 7^2 : 9^2 = 2\tfrac{1}{2} : x;$$

whence $x = 4\frac{13}{98}$, or practically 4lbs. yarn as the nearest. In dealing with lea yarns it is necessary to remember that increasing the count is reducing the weight, and that for this reason the proportions must be applied inversely. Thus, it may be desired to produce a cloth one-eleventh lighter than that made by 40's lea yarn in a 10^{00} reed. The proportions are evidently 11 : 10, and the reed should be increased in these proportions :—

$$\therefore 10 : 11 = 10^{00} : 11^{00} \text{ reed.}$$

In order to obtain a reduced diameter, the yarn number should also be increased in the proportion—

$$10 : 11 = \sqrt{40\text{'s}} : \sqrt{x},$$

$$\text{or } 10^2 : 11^2 = 40\text{'s} : x;$$

whence $x = 48{\cdot}4$, say 50's lea; or 45's lea warp and 50's lea weft.

There is still another phase of these structural alterations, viz., that of changing the weave of the cloth and at the same time preserving a similar fabric structure. This may be performed in two ways: (1) By retaining the original yarns and changing the sett;

or (2) by retaining the original sett and changing the yarns. In either way it is the diameter of the yarn which is the controlling factor.

In order to produce cloth by weaving, the warp and the weft must intersect, and in the plain $\frac{1}{1}$ weave this intersecting is at a maximum, since every warp thread interweaves with the weft each pick, and each weft thread passes over and under alternate warp threads. In a cloth of this character, therefore, with 30 warp threads per inch, there are also 30 intersections of weft per inch, giving a total of 60 thicknesses of yarn per inch across the cloth; consequently, if the cloth has 30 picks per inch, there are also 60 thicknesses per inch lengthwise. If now a second weave be introduced, say the three-leaf twill $\frac{2}{1}$, in which a warp thread remains up for two picks, intersects with the weft between the second and third picks, and again comes up between the third and first picks, it is obvious that the cloth so produced, if woven in the same sett, and with the same size of yarns as the plain cloth, is considerably looser in build or structure. In the plain weave there are three intersections for every three picks, while in the three-leaf twill weave there are only two. It will thus be seen that in the plain weave, and in simple twills, the threads, plus the intersections, serve to indicate the approximate relative values of these weaves from a structural point of view. For purposes of comparison the number of threads must be the L.C.M. of the two weaves. Thus, given the above two weaves (plain and three-leaf twill), the L.C.M. is 6.

$\therefore$ 6 threads + 6 intersections = 12 units as the relative value of the plain weave; and 6 threads +

4 intersections = 10 units as the relative value of the twill weave. In order, therefore, to make up for this reduced structural value of the $\frac{2}{1}$ twill, the threads of warp and of weft should be placed closer together, or their diameters increased in proportion to such reduction. Thus :—

$$10 : 12 = 30 : x,$$

whence $x = 36$ threads per inch for the $\frac{2}{1}$ twill ; or, if the original yarn were 14's lea, then to increase the diameter means reducing the count.

$$\therefore 6 : 5 = \sqrt{14} : \sqrt{x},$$

$$\text{or } 6^2 : 5^2 = 14 : x$$

whence $x = 9\frac{4}{9}$, say, 10's lea yarn.

Such is, in brief, an explanation of the commonly-accepted rules applicable to cloth structure. They are valuable as a means of changing from one known cloth to another, and are practically independent of the actual diameter of the yarn ; but their value is undoubtedly enhanced when it becomes possible to use them in conjunction with the actual diameter of the yarn. There is, however, a slight inaccuracy in the above theory of intersections, which we shall refer to later.

Many different methods have been suggested and tried for the purpose of determining the diameter of yarns, but from the nature of the material it is impossible to expect more than an approximately accurate result. Yarn is not incompressible ; it cannot, therefore, be measured by micrometer screw gauges. It is not spun perfectly uniform, and therefore gives unsatisfactory results with a microscopic micrometer. Different degrees of twist are applied to yarns of the same count,

therefore different diameters will result. The absolute density of any fibre can, of course, be easily obtained by displacement, *i.e.*, by weighing in air and water; but absolute density is valueless when employed for the purpose of calculating diameters, as all allowance for air space in the yarn must be purely arbitrary. It might also be imagined that the density of a jute or linen warp when heavily pressed and dressed, as on a loom beam, would be nearly equal to the density of the yarn; but so far as we have been able to investigate, such is not the case. In such a condition the average density seems to vary between 0·5 and 0·6, whereas for diameter purposes we are satisfied that it must lie somewhere between 0·75 and 0·85 for jute and linen yarns. These figures or densities we have found in several hydraulic-pressed yarn bales, and the yarn diameters which correspond to such densities are confirmed by actual maximum cloths.

If it is assumed that the density of jute in the yarn condition is 0·80, then the diameter of any thread may be calculated. In general, we have :—

$d^2 \times \frac{\pi}{4} \times l$ = cubic inches in 1lb., where l is the length in inches of 1lb. of yarn, and d is the diameter.

Also, $\frac{1{,}728 \text{ cub. in.}}{62{\cdot}5\text{lbs.} \times 0{\cdot}8}$ = number of cubic inches in 1lb. at above density.

$$\therefore d^2 \times \frac{\pi}{4} \times l = \frac{1{,}728}{62{\cdot}5 \times 0{\cdot}8}.$$

Hence $d^2 = \frac{1{,}728 \times 4}{62{\cdot}5 \times 0{\cdot}8 \times l \times \pi}$

$$d^2 = \frac{138\cdot 24}{l \times \pi}.$$

$$\therefore d = \sqrt{\frac{138\cdot 24}{l \times \pi}}$$

$$= \sqrt{\frac{138\cdot 24}{14{,}400 \text{ yds.} \times 36\text{in.} \times \pi} \times \text{count}}$$

$$= \frac{\sqrt{\text{count}}}{108}.$$

Applying a particular case, say, for 9lbs. yarn, it is seen that

$$d^2 \times \frac{\pi}{4} \times \frac{14{,}400 \times 36\text{in.}}{9\text{lb.}} = \frac{1{,}728}{62\cdot 5 \times 0\cdot 8}.$$

$$\therefore d^2 = \frac{4 \times 9 \times 1{,}728}{3\cdot 1416 \times 14{,}400 \times 36 \times 62\cdot 5 \times 0\cdot 8}$$

$$= \frac{1}{1{,}309}.$$

Hence $d = \frac{1}{36}$.

Or applying the previous result for d, we have

$$d = \frac{\sqrt{\text{count}}}{108} = \frac{\sqrt{9}}{108}$$

$$= \frac{3}{108}.$$

$$= \frac{1}{36}, \text{ as before.}$$

By assuming 0·84 as the density for linen yarns,

and adopting a precisely similar calculation, we may obtain the diameters of linen yarns. Thus :—

$$d^2 \times \frac{\pi}{4} \times l = \text{cubic inches in 1lb.}$$

$$\frac{1{,}728}{62\cdot5\text{lbs.} \times 0\cdot84} = \quad " \qquad "$$

$$\therefore d^2 = \sqrt{\frac{1{,}728 \times 4}{62\cdot5 \times 0\cdot84 \times l \times \pi}}$$

$$= \sqrt{\frac{1{,}728 \times 4}{62\cdot5 \times 0\cdot84 \times 3\cdot1416 \times 300 \times 36\text{in.} \times \text{count.}}}$$

$$= \sqrt{\frac{1}{257 \times \text{count.}}}$$

$$\therefore d = \frac{1}{16 \times \sqrt{\text{count.}}}$$

—*e.g.*, the diameter of 25's lea yarn is :—

$$\frac{1}{16 \times \sqrt{25}}$$

$$= \frac{1}{16 \times 5}$$

$$= \frac{1}{80} \text{ of an inch.}$$

These results enable one to obtain the diameter quickly—indeed, in many cases a sufficiently accurate result may be obtained mentally. The reciprocals of the diameters may be found by extracting the square root of the yards per pound, and deducting 10 per cent.

for jute and 7½ per cent. for linen. The following tables have been calculated in this manner :—

Count.	Square Root of Yards Per Pound, Minus 10 Per Cent.	Count.	Square Root of Yards Per Pound, Minus 7½ Per Cent.
Lb.		Lea.	
2	76·5	1	16·0
2½	68·5	2	22·5
3	62·5	3	28·0
3½	57·5	4	32·0
4	54·0	6	39·0
5	48·5	8	45·0
6	44·0	9	48·0
7	41·0	10	50·5
8	38·0	12	55·5
9	36·0	14	60·0
10	34·0	16	64·0
12	31·0	18	68·0
14	29·0	20	71·5
16	27·0	24	78·5
18	25·5	25	80·0
20	24·0	28	85·0
24	22·0	30	88·0
30	20·0	32	90·5
48	15·5	35	94·5
—	—	40	101·5
—	—	45	107·5
—	—	48	111·0
—	—	50	113·5
—	—	55	119·0
—	—	60	124·0
—	—	65	129·0
—	—	70	134·0
—	—	75	139·0
—	—	80	143·0
—	—	90	152·0
—	—	100	160·0

We have made no investigations concerning the densities of the other fibres in the yarn condition, but,

if we take the late Mr. Ashenhurst's measurements for granted, the approximate diameters may be obtained by similar simple formulæ. Thus :—

$$\text{Diameter of woollen skein} = \frac{1}{13{\cdot}5\sqrt{\text{count}}}.$$

$$\text{Diameter of worsted} = \frac{1}{21{\cdot}3\sqrt{\text{count}}}.$$

$$\text{Diameter of cotton} = \frac{1}{26{\cdot}2\sqrt{\text{count}}}.$$

CHAPTER XI.

The Structure of Fabrics.

WHEN the diameters of yarns composed of any kind of fibre have been determined to a moderate degree of accuracy, it is possible, to a certain extent, to utilise this information scientifically in the building-up of fabrics. It must, of course, be understood that such diameters refer generally to the measurements of yarns in their normal condition of twist—that is, with the ordinary number of turns per inch. They must, therefore, not be taken as applying to yarns in all conditions, since a variation of twist will naturally have an influence upon the diameter of the thread.

We are well aware that manufacturers and designers do not, except on very rare occasions, seek to apply mathematical rules in the structure of their cloths. Indeed, the natural and almost universal demand for cheap fabrics almost precludes any such proceeding. Still, with a fair approximation of the diameter of any given yarn, it is possible, and sometimes desirable, to determine the maximum number of threads and picks per inch which can be woven into a cloth under given weave conditions. Having once determined this maximum number, it is evident that any smaller quantity may, within reasonable limits, be inserted according

to the necessities of the case. Cheap cloths may, of course, be produced in many different ways—*e.g.*, by imitating a given cloth with inferior yarns of the same fibre, or in yarns of a different and cheaper fibre; by retaining the yarns and reducing the sett; or by substituting a finer count in the same or in a coarser sett, &c. Without in any way expressing an opinion on the merits or demerits of these methods from a business point of view, it is sufficient to know that they are resorted to for cheapness, and they therefore serve to demonstrate the fact that mathematical rules are unnecessary for cloth structure except in very special cases. Such rules are nevertheless valuable, and on several occasions within our own knowledge the theoretical rules of cloth structure have been applied in practice with satisfactory results. In what follows, therefore, our chief object will be to show that it is possible to determine to a high degree of accuracy the maximum number of threads and picks which it is desirable to put into a fabric under given yarn and weave conditions.

In all previous works with which we are familiar, the structure of the cloth has been treated as if it were the interlacing of a series of perfectly flexible, but incompressible, threads, or rather wires, which, throughout the weaving process, retained inviolate a perfectly circular and incompressible form. When yarns are newly spun, the outline of a cross section of a thread undoubtedly approximates closely to that of a circle; but, besides being flexible, it must be remembered that since yarn is compressible its sectional form is most unstable, and is willing and ready to adapt itself to almost any new shape. Consequently, instead of

considering the question as a series of parallel lines intersecting a series of circles, consideration must be given to the sectional form which the yarn is likely to assume when in the cloth. There are, of course, rare occasions, such as in art canvas for embroidery purposes, and in straining cloths, where it is desirable to preserve the circular form or wire-like appearance of the thread, but in by far the greater proportion of fabrics it is not considered desirable to do so.

In cloths of the plain weave there are what might be termed two extremes of fabric structure, viz., those cloths with a maximum number of warp threads, in which the weft threads lie almost perfectly straight, while the warp threads do all the bending; and those of the opposite extreme, with weft at a maximum and doing all the bending, while the warp lies practically straight. There is also an infinite number of conditions between these. We shall now proceed, however, to consider more particularly the case of the first extreme, or that in which the warp predominates to such an extent that the weft is compelled to take an almost perfectly straight course in the cloth. The warp threads in these fabrics, where two or more fold, are usually slightly softer twisted than the normal, with a view to facilitate their spreading on the surface of the fabric, and to enable them to yield more easily to pressure at the points of intersection of the weft. In this, however, as in all other cases, unless specially mentioned otherwise, we shall assume that the yarns are single, and that they possess the regular amount of twist.

Figs. 19 and 20 show respectively weft and warp sections of such cloths, in which the weft threads are

marked P and the warp threads T, while both are alike in diameter. These views have been generally regarded as correct representations of such sections, and have the centres of all the weft threads P in the same horizontal plane X Y. If such conditions obtained, the estimation of the maximum number of picks per inch would be an easy matter, for

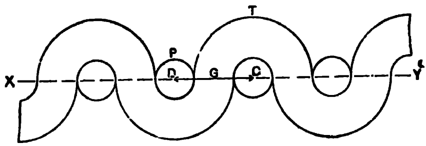


FIG. 19.

the distance between each pair of weft threads is clearly the length of the line D C. Consequently we should have $\frac{1}{p+t}$ =maximum picks per inch, where p = the diameter of the weft, and t = the diameter of the warp. Thus, if weft and warp were of equal diameter, say $\frac{1}{40}$in., then

$$\frac{1}{\frac{1}{40}+\frac{1}{40}}=\frac{1}{\frac{1}{20}}=20 \text{ picks per inch maximum.}$$

Now we think it is perfectly obvious that an ordinary

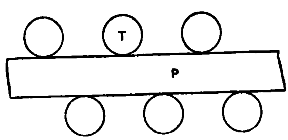


FIG. 20.

warp thread, under the strain to which it is subjected in weaving a maximum cloth, is incapable of retaining the sectional form indicated at T in Fig. 20. When passing over and under the weft P, no lateral support

is given to the warp threads; each one is, therefore, at perfect liberty to expand towards the selvages. It is certain that such expansion does occur, and it is due to the general resistance of the weft to the combined tensiled an compressive strain of the warp. Consequently, instead of the sectional form of the thread

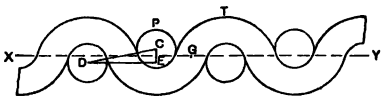


FIG. 21.

remaining that of a circle, as at T in Fig. 20, it becomes more or less elliptical, as indicated at T in Fig. 22. The weft threads P are displaced or corrugated in a greater or less degree, and we have endeavoured to show correct representations of such weft and warp sections respectively in Figs. 21 and 22, with a plan of the cloth in Fig. 23. Where the warp intersects with the weft (as at G in Figs. 19 and 21) the case is somewhat different. If we assume that the diameter of the warp is $\frac{1}{40}$in.,

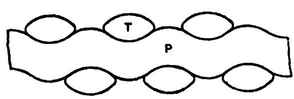


FIG. 22.

and that it has been set in the reed at exactly 40 threads per inch, then we may assume that, when the warp crosses the weft as at G, every warp thread is touching its neighbour on both sides. Now, any pressure exerted on the weft as a result of beating up will also be exerted on these warp threads. But pressure on the warp in

one direction, or in the length of the piece, would produce in these threads a tendency to expand at right angles—*i.e.*, across the cloth. This tendency to expand is, however, met by an equal and opposite resistance on the part of every thread, consequently at the points of intersection we get a simple alteration of the sectional form of the warp thread from a circle to that of a rectangle.

Now, although the density of the fibre at this part is not exactly uniform, it is practically at its maximum for yarns. If, therefore, we assume this state as being absolutely correct, the sectional area of the rectangle will be the same as that of the circle. But the longer side D of this rectangle must be the same as the diameter of the circle (for the 40 threads per inch of warp take up all the space in the width of the cloth), while the shorter side may be represented by *d*.

Now, in this case, the area of the rectangle = the area of the circle.

$$\therefore \mathrm{D} \times d = \mathrm{D}^2 \times \frac{\pi}{4}, \text{ or } d = \mathrm{D} \times \frac{\pi}{4}.$$

We therefore see that, with a warp set in such a manner, the value of the thickness of the warp at the point of intersection G, as a factor for determining the maximum number of picks per inch, may be only $\frac{\pi}{4}$, or 0·7854 time its original diameter.

While the weft of such fabrics is subjected to a considerable amount of pressure, and a slight displacement results, we think that, due to the manner in which it is encircled and supported by the warp, it may be

considered as retaining its original cross section and diameter.

In addition to the question of the actual or effective thickness of the threads themselves, there is also the question of their disposition to be considered. In the present instance the displacement of the weft P (Fig. 22) from the perfectly horizontal line is very slight; still, it is sufficient to modify the result in the cloth both from the theoretical and the practical points of view. In Fig. 21 the centres of successive weft threads are not in the same horizontal plane X Y, but are displaced equally

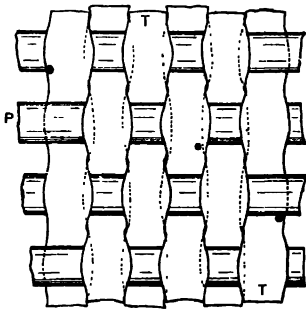


FIG. 23.

above and below this central line of the piece, in this instance to the extent of about 10°. Now while the distance D C from centre to centre of any two successive picks is still the effective diameter of warp plus the effective diameter of the weft, this line is not now in the same horizontal plane as that of the piece, with the result that the horizontal distance between each pair of weft threads is reduced. This allows of a slight increase in the number of picks per inch. In other words, in the triangle C D E, the line D C is the distance from

centre to centre of two successive picks, while the line D E is their distance apart in the horizontal plane of the piece.

But $\frac{DE}{DC}$ = cosine C D E, or cos. D, which has been found by measurement to be 10°, and the cosine of 10° = 0·9848.

$$\therefore DE = DC \times 0{\cdot}9848, \text{ or, picks per inch,}$$

$$= \frac{1}{DC \times 0{\cdot}9848}.$$

But in the present case D C = diameter of weft + (diameter of warp × 0·7854), therefore the actual picks per inch

$$= \frac{1}{[\text{dia. of weft} + (\text{dia. of warp} \times 0{\cdot}7854)] \times 0{\cdot}9848}.$$

Given that the warp and the weft are again equal in diameter, say $\frac{1}{40}$in., or 0·025in., then

$$\frac{1}{[0{\cdot}025 + (0{\cdot}025 \times 0{\cdot}7854)] \times 0{\cdot}9848} = 22{\cdot}75 \text{ picks per inch,}$$

an increase of nearly three picks per inch, or about 13 per cent., when allowance is made for the compression of the warp, and for the deflection of the weft from the straight line.

Since in these cloths the cosine of the angle D is for all practical purposes equal to unity, it may be neglected entirely, and the simple formula $\frac{1}{p + \frac{\pi}{4} t}$ used for the maximum number of picks where the threads per inch is the reciprocal of the diameter of the yarn.

There are, however, cloths of this type and weave in which the number of warp threads per inch exceeds

the reciprocal of the diameter of the yarn, and we should like to notice at least two sets of circumstances in which this might occur. It is quite clear that, if the number of warp threads per inch be increased beyond the reciprocal of the diameter, the thickness of the warp thread across the cloth and at the points of intersection of the weft would be reduced in a corresponding degree, and that in consequence a greater resistance would be offered to the beating-up of the weft.

A corresponding reduction of the picks per inch would also take place, provided the density of the yarn remains unaltered. At first sight there appears to be no theoretical limit to this increase of the number of warp threads beyond the reciprocal of the diameter, although it must naturally coincide with the limit of compressibility of the yarn. We consider that the practical limit should be reached when the number of threads per inch equals $\frac{\text{the reciprocal of the diameter}}{0 \cdot 7854}$ —*i.e.*, when the section of the warp thread at the point of intersection with the weft is again a rectangle, but with its longer side now running in the direction of the length of the piece, and its shorter side across the piece. In this case the thickness of warp between any two successive picks would be exactly its circular diameter, and the distance from centre to centre of such picks or the length of the line D C of the triangle referred to would be exactly the diameter of the warp + the diameter of the weft. The picks per inch in such circumstances would therefore be :—

$$\frac{1}{(\text{diameter of warp} + \text{diameter of weft}) \times 0 \cdot 9848}, \text{ if}$$

deflection of the weft were again 10°, and this would differ very little from the previous case.

There may be a number of cases between each extreme, but the mean extreme is reached when the cross section of the warp at the points of intersection indicated is a square, or when the number of threads per inch of warp =

$$\frac{\text{reciprocal of diameter}}{\sqrt{\frac{\pi}{4}}}, \text{ or } \frac{\text{reciprocal of diameter}}{0 \cdot 886}.$$

If we further assume that the diameter of the weft is constant, then the picks per inch in such cases would be $\frac{1}{[(\text{dia. of warp} \times 0 \cdot 886) + \text{dia. of weft}] \times 0 \cdot 9848}$.

Since this type of plain cloth is undoubtedly that in which the greatest quantity of yarn can be placed—that is, the greatest aggregate number of warp threads plus weft threads per square inch—let us now calculate the total number possible under the three conditions indicated.

For case No. 1, in which the number of warp threads per inch is exactly the reciprocal of the diameter, we shall assume that the warp and the weft are alike, viz., 9lbs. jute, the diameter of which is :—

$$\frac{\sqrt{9\text{lbs.}}}{108} = \frac{3}{108} = \frac{1}{36} \text{ of an inch,}$$

and that the deflection of the weft from the horizontal is 10°. The warp sett is obviously 36 threads per inch, and the picks per inch will be :—

$$\frac{1}{\left[\frac{1}{36} + \left(\frac{1}{36} \times 0 \cdot 7854\right)\right] \times 0 \cdot 9848} = 20 \cdot 5.$$

But 36 warp threads plus 20·5 weft threads per inch =56·5 threads per square inch as the maximum number of threads of 9lbs. yarn which can be put into a cloth with the plain weave and arranged on the lines indicated.

In case No. 2, where the sett of the warp is $\frac{\text{the reciprocal of the diameter,}}{0\cdot7854}$ we shall assume a cloth of the flax canvas type, made from 6lbs. flax warp and 16lbs. flax weft. The diameter of 6lbs. flax yarn $= \frac{1}{16} \times \frac{1}{\sqrt{\frac{48}{6}}} = \frac{1}{45}$ in., and the diameter of 16lbs. flax yarn $= \frac{1}{16} \times \frac{1}{\sqrt{\frac{48}{16}}} = \frac{1}{28}$ in.; the deflection of the weft from the horizontal to be only 5°, since the weft is so much heavier than the warp. Cos. D in this case is 0·996, a figure which is almost negligible. From our assumption, the threads per inch of warp will be $\frac{45}{0\cdot7854} = 57\cdot3$, and the picks per inch, since the warp is compressed across the cloth, will be $\frac{1}{\left(\frac{1}{45} + \frac{1}{28}\right) \times 0\cdot996}$ $= 17\cdot31$. ∴ 57·3 threads of warp + 17·3 threads of weft = 74·6 threads per square inch.

For case No. 3, where the warp sett is the $\frac{\text{reciprocal of diameter}}{0\cdot886}$, let us take for both warp and weft a 25-lea yarn with a diameter of $\frac{1}{16} \times \frac{1}{\sqrt{25}} = \frac{1}{80}$ in., and let the deflection of the weft be 10°. The maximum

number of warp threads per inch will be $\frac{80}{0.886}=90.3$, and the picks per inch, since the warp is compressed equally in both directions at the points of intersection, will be $\frac{1}{[(\text{dia. of warp}\times 0.886)+\text{dia. of weft}]\times 0.9848}=$ $\frac{1}{[(0.0125\times 0.886)+0.0125]\times 0.9848}=43.1$ picks per inch. 90 threads warp + 43 threads weft = 133 threads per square inch, and similarly with yarns of other counts.

In the above three cases we have endeavoured to show the maximum number which it is possible to obtain with the assumed yarn and weave conditions—that is, with the warp packed as closely together as is possible or desirable; with the weft practically straight and the warp doing all the bending, causing the warp contraction to be at a maximum and the contraction in width at a minimum. We think that it will also have been observed that in such conditions the diameter of the weft has no influence whatever on the sett of the warp.

From the foregoing it will be observed that the so-called "angle of curvature" has not been mentioned in connection with the calculation of the picks per inch. It is the angle of deflection of the weft threads themselves from the horizontal plane which determines the base of the triangle, and therefore the horizontal distance between each pair of weft threads. It is quite true that the picks per inch could be found by taking the base of the triangle formed by this angle of curvature, but when these angles approach 45°, as in the above cases,

a slight error of judgment in the angle itself leads to unsatisfactory results. On the other hand, when the calculation is made to depend upon the angle of deflection of the weft, a small error in estimating such angles makes very little difference in the result.

By reversing all the above conditions—*i.e.*, by reducing the warp sett—and by increasing the weft sett or picks per inch until they equal the former warp sett, we still preserve a maximum cloth, but in this case the warp would be practically straight, with contraction in length at a minimum, while the weft would do all the bending and contraction in width would be at a maximum. Figs. 21 and 22 may be taken as representing such conditions if we consider the former as a section through the warp, and the latter as a section through the weft. Now between these two extremes it is obvious that there may be innumerable stages which it is impossible to define, a fact which accounts for our previous remarks concerning the application of mathematical rules to cloth structure in general. One or two general features of the change are, however, very clear —viz., that in reducing the number of warp threads their necessity for extreme bending is reduced, since the weft is permitted to bend more, and that increased bending of the weft with a reduced bending of the warp increases the possible number of weft threads per inch. When this change has reached its mean—*i.e.*, when warp and weft (alike in count) have become equal in number—and when the bending or deflection of each from the straight line is the same value, we have what is commonly termed a perfectly balanced plain cloth.

In Figs. 19 and 21 the warp threads T are represented

as bending over and under the weft threads P, but in such a cloth there is a second series of warp threads, which partly encircles the weft threads on the sides opposite to those shown in the diagrams. The two sets of warp threads inclose the weft threads, consequently the fabric is composed of three thicknesses of yarn, the upper and the lower surfaces being made entirely of warp, while a layer of weft lies between them. In the so-called perfectly-balanced plain cloth, however,

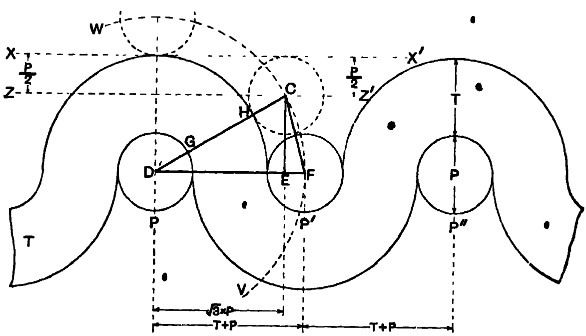


FIG. 24.

both surfaces of the fabric are composed equally of warp and of weft; that is, equal portions of both sets of threads appear both in the highest and in the lowest planes of the cloth. Since the weave causes every thread of the warp, and every pick of the weft, to assume these positions alternately in equal portions, any section through the weft (or through the warp) will show that any two adjacent picks of weft (or threads of warp) appear on opposite surfaces of the fabric.

P, P′, P″ in Fig. 24 are the sections of three successive picks in a maximum plain cloth intended to be of this

character, where both warp and weft threads are of the same count. The centres of these three picks are represented as being in the same horizontal plane, but, by hypothesis, alternate picks should appear in the upper and in the lower planes respectively. Supposing picks P and P″ remain in the lower plane, then the highest point of P′ must be raised to the level of the highest point of the warp thread T. X X′ represents this level, and ZZ′ is drawn parallel to, and at a distance $\frac{P}{2}$ under, XX′ (P equals the diameter of the weft); then the centre of the pick P′, when the latter is in its true position, must lie on this line ZZ′ in order that its highest point may be on the same level as the highest point of the thread T. With D as centre and D F as radius the arc V W is described. The point C, where this arc cuts the line ZZ′, is the position required, and the pick P′ is shown in its new position by a dotted circle.

Since each curve is part of a perfect circle and the line D C is normal to all, D G and H C are each equal to the radius of the weft P, while G H equals the diameter of the warp T. D C is therefore equal to the diameter of the warp T plus the diameter of the weft P; since in this case the diameters are equal, it follows that D C is equal to twice the diameter of either yarn. Therefore,

$$\frac{CE}{CD} = \frac{T}{T+P} = \frac{T}{2T} = \tfrac{1}{2}$$

That is, sine C D E $= \frac{1}{2}$, $\therefore$ angle C D E $= 30°$.

Also $\frac{DE}{CD} = \cos.\ CDE = \cos.\ 30°$.

$$\therefore\ DE = CD \times \cos.\ 30° = (T + P) \times 0{\cdot}866$$
$$= 2P \times 0{\cdot}866 = 1{\cdot}732\ P, \text{ or } 1{\cdot}732\ T,$$

Without considering the angle, the same result may be obtained as follows :—

$$D E^2 = C D^2 - C E^2 = (T + P)^2 - T^2$$
$$= T^2 + 2 T P + P^2 - T^2 = 2 T P + P^2$$
$$= 3 P^2 \therefore D E = \sqrt{3} \times P = 1 \cdot 732 \text{ P, or } 1 \cdot 732 T.$$

In other words, while the distance from D to C is the diameter of the warp plus the diameter of the weft, the distance D E—*i.e.*, the effective or horizontal distance from centre to centre of any two adjacent threads—is only $\sqrt{3}$ times the diameter P, or 0·866 times the distance D C. Hence the setting—*i.e.*, the number of threads per inch (or the number of picks per inch) for fabrics of this character, where the yarns are practically equal—is found by the formula :—

$$\frac{1}{D E} = \frac{1}{(T + P) \times 0 \cdot 866} = \frac{1}{1 \cdot 732 T}, \text{ since T and P are equal.}$$

$$= \frac{\text{Reciprocal of diameter of T}}{1 \cdot 732}.$$

$$= \text{Reciprocal of T} \times 0 \cdot 577.$$

What has hitherto, theoretically at least, been considered as the proper distribution of threads and picks for this class of fabric is illustrated in Fig. 25. The triangle C D E is of exactly the same dimensions as that in Fig. 24, and so also are the triangles J E D and J K D; therefore the average angle formed by the curvature of the warp—*i.e.*, angle J E D or angle J K D—is also one of 30°. If this theoretical condition were fulfilled, each angle would remain equal to 30°, but this would be to assume again that the yarn is incompressible and stable in its circular form.

The term "perfectly balanced cloth" may be appropriately given to all those fabrics in which the sections through the warp and the weft are identical, but it is usual to consider the term as applying particularly to those sections which possess a wire-like structure shown in Fig. 25. There are cases where this ideal state is approached, but in no case is it actually reached. If, however, such a fabric were possible, an examination of a plan of the cloth would show a large proportion of unoccupied space between the threads and the picks.

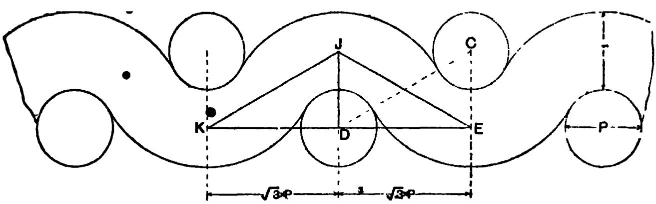


FIG. 25.

In practice, however, the threads and picks flatten out into a more or less ribbon-like form, and fill up every available crevice in the cloth. These contentions are clearly illustrated in Figs. 26 and 27, which show respectively plans of the theoretical and of the actual cloth, with corresponding warp and weft sections. While the sections in the former figure have been drawn by the method already described as giving the maximum number of threads and picks, yet a glance at the plan produced from these sections shows clearly that such a cloth would be very open indeed, and quite unlike what plain cloths usually appear. As a matter of fact, the space between each pair of threads or picks in this figure is nearly as great as the diameter of the yarn itself—

the actual measurements in the drawing being in the proportion of 42 per cent. space to 58 per cent. yarn.

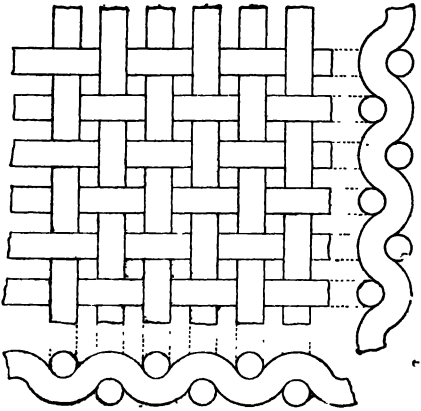


FIG. 26.

Still, in spite of this apparently anomalous state of things, the figure represents the correct method of determining the maximum number of threads and picks

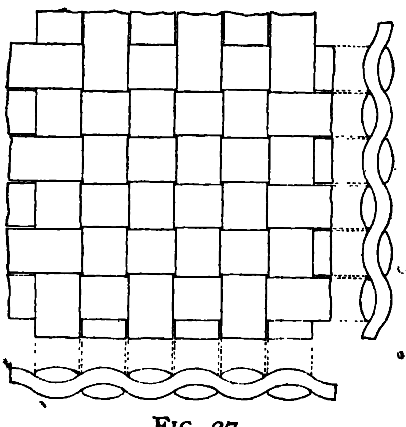


FIG. 27.

which it is desirable to put into a balanced plain cloth with equal counts of warp and weft.

It has already been stated, and also illustrated in Fig. 27, that, due to the strain of weaving, both threads flatten out into a ribbon-like form, with a more or less elliptical cross-section. It might be imagined that such a flattening of the thread, while filling up the open spaces between the threads, might also permit of the latter being "sett" closer together. Instead of this being the case, the tendency is rather the other way,

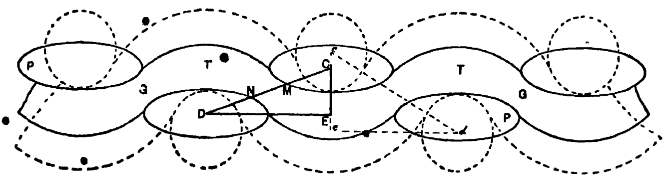


FIG. 28.

for immediately the threads lose the circular form and begin to assume that of an ellipse, there is less space available at the points of intersection between two adjacent threads or picks than is necessary for the passage of the reduced thickness of the interweaving weft or warp yarn. The explanation of this is indicated in Fig. 28. In the transition from circles to ellipses the centres of every pair of adjoining threads approach the central horizontal line of the cloth (not shown in the figure); the distance between these centres is therefore gradually decreasing. In addition, the distance C M or D N in the horizontal ellipse is always greater than the radius of the circle; in the position shown each is

even greater than the minor axis of the ellipse—that is, greater than C E. By calculation, C E = 0·6 P, where P = the diameter of the dotted circle, and C D = 1·83 P; but since C M and D N are each appreciably greater than C E, it follows that N M must be appreciably less than 0·63 P, and consequently not greater than the minor axis of the ellipse. This is quite evident in the figure, where the dotted circles and curves indicate the theoretical condition of things, while the ellipses and the curves in full lines indicate approximately the conditions in the cloth. Ellipses P were carefully constructed to give exactly the same area as the circles; the major axis was taken slightly less than the distance D E, the minor axis calculated, and the thickness of the warp thread T arranged to correspond with the minor axes of the ellipses. It is obvious that at the points of intersections G, which are even less than the line N M, the space allowed for the interweaving thread is less than the minor axis of the ellipse, and that if the conditions indicated are to continue, the thread must be more or less compressed at these points. Evidence of the fact that such compression does occur may be obtained by anyone who cares to examine closely threads which have been carefully withdrawn from a cloth of this character.

Another feature of the change worth noting is that while in the theoretical condition the angle of deflection of the weft, as well as the angle of curvature of the warp, is one of 30°, in the new or actual condition this angle is considerably reduced, and is found both by calculation and by measurement to be one of about 19°. Notwithstanding these changes we still think that the setting of

cloths of this character should be calculated from the formula—

$$\frac{1}{0{\cdot}866\,(T+P)} \text{ or } \frac{\text{reciprocal of diameter}}{1{\cdot}732}.$$

Thus, given a linen warp and linen weft of 36's lea with a diameter of $\frac{1}{16} \times \sqrt{\frac{1}{36}} = \frac{1}{16} \times \frac{1}{6} = \frac{1}{96}$ of an inch, the yarn setting would be

$$\frac{1}{0{\cdot}866\left(\frac{1}{96} + \frac{1}{96}\right)} = \frac{1}{0{\cdot}866 \times \frac{1}{48}} = \frac{48}{0{\cdot}866}$$

= approximately 56 threads per inch of warp and weft; or, given a 9lbs. jute yarn with a diameter of $\frac{1}{108} \times \sqrt{9} = \frac{3}{108} = \frac{1}{36}$ of an inch, then the proper yarn setting would be $\frac{36}{1{\cdot}732} = 21$ threads per inch of warp and weft.

In view of the importance of this branch of the subject, particulars are appended of the analysis of a few linen fabrics of this class which have been taken at random, but which appear to approach the maximum condition. They serve to show how closely theory and practice coincide in this respect. A comparison of the column giving the average threads per inch with the last column, which gives the maximum number advisable according to theory, shows a close approximation between the two. In only one instance—viz., No. 2—is the actual number of threads per inch in excess of the theoretical

number, all the other values being about 4 per cent. under.

	Analyses.				Deductions.			
Examples.	Threads per Inch.		Lea Counts.		Average Threads per Inch.	Average Count.	Reciprocal of Diameter of Average Count.	Reciprocal / 1·732
	Warp.	Weft.	Warp.	Weft.				
1	64	62	44·5	56	63	50	112	64·6
2	62	61	42·6	42·6	61·5	42·6	104	60
3	38	39	17·2	20·8	38·6	19	70	40·4
4	45	44⅓	27·3	23·6	44·5	25·5	80	46·2

In cases where there is only a slight difference between the counts of the warp and the weft yarn, a sufficiently accurate and practical method is to take the average of the two and work from this basis; this is sufficiently illustrated in the above table. But where there is a great difference between the counts of the warp and weft, and where it is still desired to approach the structure of a balanced fabric, it is essential that the warp and the weft sections—so far as the determination of the threads and the picks per inch is concerned—be treated independently as two separate structures.

Figs. 29 and 30 show respectively weft and warp sections of such a fabric, and, for purposes of illustration only, the diameters of the yarns have been taken in the ratio of 2 to 1, or in a ratio of 4 to 1 in the actual weights of the yarn. Were such a difference attempted in practice, the yarns would probably be unable to assume the relations indicated in the figure—*i.e.*, the relations which hold in balanced cloths. In order, however, to more clearly illustrate the different dimensions, it is

necessary to exaggerate the difference in the diameters of the yarns; but it must be clearly understood that this is done purely for demonstration purposes. Both figures have been constructed on the same general principle as that explained in connection with Fig. 24. In Fig. 29, D C = T + P = diameter of warp + diameter of weft.

$$CE = T \text{ and } DE^2 = DC^2 - CE^2 \therefore DE = \sqrt{DC^2 - CE^2} = \sqrt{(T+P)^2 - T^2} = \sqrt{P^2 + 2TP}.$$

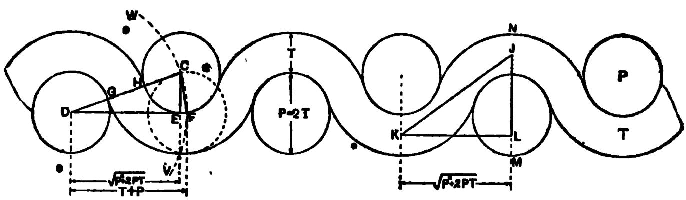


FIG. 29.

The picks per inch for such a fabric made from 8lbs. jute warp, with a diameter of $\frac{1}{38}$ of an inch, and 16lbs. jute weft, with a diameter of $\frac{1}{27}$ of an inch, would be—

$$\frac{1}{\sqrt{P^2 + 2TP}} = \frac{1}{\sqrt{\left(\frac{1}{27} \times \frac{1}{27}\right) + 2 \times \frac{1}{38} \times \frac{1}{27}}} =$$

$$\frac{1}{\sqrt{\frac{1}{729} + \frac{1}{513}}} = \sqrt{301} = 17 \cdot 3 \text{ picks per inch.}$$

In Fig. 30 D C again = T+P, but CE = P and

$$DE = \sqrt{DC^2 - CE^2} = \sqrt{(T+P)^2 - P^2} = \sqrt{T^2 + 2TP}.$$

The threads per inch of warp would be

$$\frac{1}{\sqrt{T^2+2TP}} \quad \frac{1}{\sqrt{\left(\frac{1}{38}\times\frac{1}{38}\right)+2\times\frac{1}{38}\times\frac{1}{27}}}$$

$$\frac{1}{\sqrt{\frac{1}{1,444}+\frac{1}{513}}} = \sqrt{379} = 19 \cdot 4 \text{ threads per inch.}$$

In Fig. 29 the average direction of the warp is shown by the hypotenuse of the triangle J K L, the angle K of which is usually termed the angle of curvature; but it must be clearly understood that this triangle has no connection whatever with the triangle C D E upon which the above calculations are based, although the

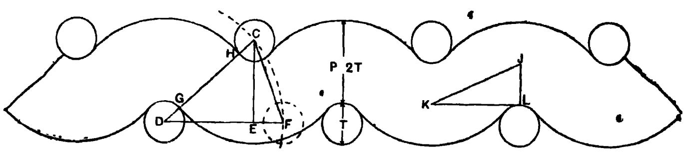


FIG. 30.

base in each case is necessarily of the same value. To find the angle C D E, it is evident from the construction that

$$\frac{C\,E}{C\,D} \text{ or sine } C\,D\,E = \frac{1}{3};$$

$$\therefore \text{angle } C\,D\,E = 19^\circ\,28'\text{—say, } 19\tfrac{1}{2}^\circ.$$

For angle J K L the total height M N = T + P, but M L and N J are each equal to $\frac{T}{2}$; $\therefore$ J L = P.

Also K L in the same figure, being the distance between two successive picks, is equal to D E;

$$\therefore K\,L = D\,E = \sqrt{P^2+2\,T\,P}.$$

$$\text{But Tan } \angle \text{ J K L} = \frac{\text{J L}}{\text{K L}} = \frac{\text{P}}{\sqrt{\text{P}^2 + 2\,\text{T P}}}$$

$$= \frac{2\text{T}}{\sqrt{4\,\text{T}^2 + 4\text{T}^2}} \text{ since P } = 2\text{T}$$

$$= \frac{2\text{T}}{\text{T}\sqrt{8}} = \frac{2}{\sqrt{8}} = \frac{1}{\sqrt{2}} = 0{\cdot}7071;$$

$\therefore$ angle J K L $= 35° \, 16'$.

The values of the angles thus found refer to those in the figure, where P = 2T. For the corresponding values in any other case it is only necessary to introduce the proper diameters of the component yarns.

Figs. 29 and 30 might be used to indicate respectively warp and weft sections of a cloth where the warp is twice the diameter of the weft, but the procedure would be identical with that already gone through, with, of course, the necessary alterations in the values of the warp and the weft.

The usual method of obtaining the number of threads and picks when changing from a plain to a twilled cloth has already been referred to. This method is applicable only to those cases where there is a practical identity in the counts of the warp and weft yarns, and, moreover, it is based upon the assumption that the intersections are of the same value as the thickness of the threads themselves as regards the horizontal plane of the piece. Since such assumption is only true for those cases where one set of threads (either warp or weft) lies perfectly straight, it is evident that this commonly accepted intersection theory is limited in its application to these cases alone, and is further confined to such of these that have warp and weft of approximately equal counts.

It is not applicable to the so-called balanced fabrics. This theory states that for an equal number of threads in each cloth (conveniently taken as the L.C.M. of one repeat each of the two weaves), threads + intersections in required weave : threads + intersections in given weave = threads per inch in given cloth : threads per inch in required cloth.

Thus, supposing it is required to apply the above in a change from a plain cloth with 8 threads per inch to a $\frac{3}{3}$ twill cloth, then :—

$$(6+2):(6+6) = 8:x$$
$$i.e.,\ 8 : 12 = 8:x$$
$$\text{Whence } x = 12.$$

This is quite true numerically, but if the values for the threads as well as for their intersections are introduced, as shown at X and Y (Fig. 31), and an equal diameter D is assumed for warp and weft, then :—

(6 thds. + 2 intersections of $\frac{3}{3}$ twill) : (6 thds. + 6 intersections of $\frac{1}{1}$ plain) should equal 8 : 12;

i.e., $(4\text{ D}+2\sqrt{3}\text{D}):(6\times\sqrt{3}\text{D})$ should equal 8 : 12

$12\,(4\text{ D}+2\sqrt{3}\text{D})$	,,	$8\,(6\times\sqrt{3}\text{ D})$
$48\text{ D}+24\sqrt{3}\text{ D}$	,,	$48\sqrt{3}\text{ D}$
48 D	,,	$24\sqrt{3}\text{ D}$
2 D	,,	$\sqrt{3}\text{ D}$
i.e., 2	,,	1·732

—which is impossible.

A more conclusive proof is perhaps supplied by the diagrams themselves, where X shows 8 threads and the corresponding intersections of the plain weave, and Y shows 12 threads and the necessary intersections of the $\frac{3}{3}$ twill. According to the intersection theory, the

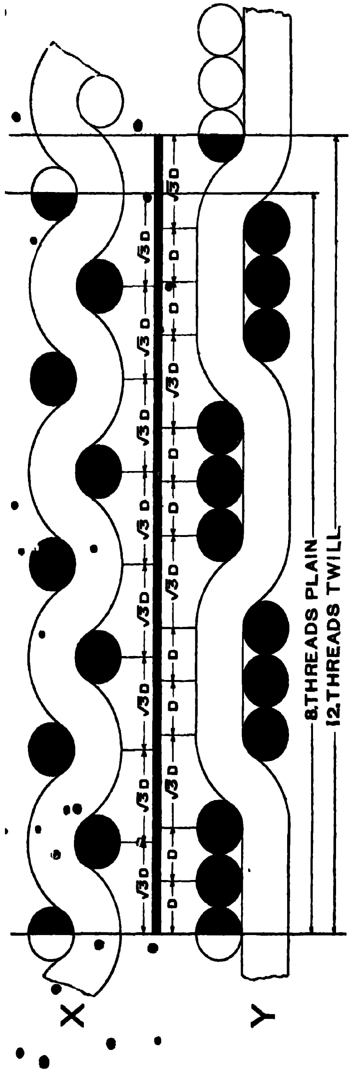


FIG. 31.

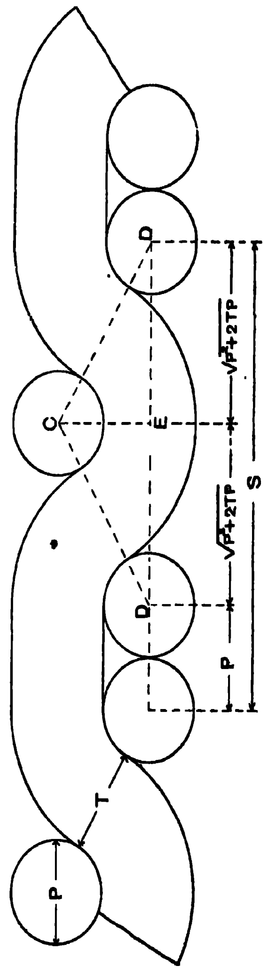


FIG. 32.

space occupied by the latter should be equivalent to the space occupied by the former. These diagrams, which were drawn with extreme care, clearly show that such is not the case. According to simple geometrical construction, the 12 threads of the twill weave plus their intersections occupy a considerably greater space than do the 8 threads and 8 intersections of the plain. If this comparison is reduced to figures, and unity assumed as the diameter of warp and weft, it is found that

In X, space occupied by 8 thds. in plain weave $= 8\sqrt{3}\,D.$
$= 8 \times 1{\cdot}732$
$= 13{\cdot}856.$

In Y, ,, ,, 12 ,, $\frac{3}{3}$ twill $= 8\,D + 4\sqrt{3}\,D.$
$= 8 + 4 \times 1{\cdot}732.$
$= 14{\cdot}928.$

Due to the foregoing considerations it is advisable, and much simpler, to treat each case separately from first principles, and in the first instance the case of the three-leaf twill $\frac{2}{1}$ will be considered. As shown in Fig. 32, one complete round of the weave consists of three picks of weft and two intersections of the same warp thread (or *vice versa* if the figure is considered as a warp section), the total space occupied being indicated by S. Clearly this space S consists of P + $2\sqrt{P^2 + 2\,T\,P}$, where P and T are the diameters of the weft and warp respectively. Since there are three picks in the round, it follows that the average space occupied by each pick is

$$\frac{P + 2\sqrt{P^2 + 2\,T\,P}}{3}$$

and that the picks per inch for a maximum balanced cloth should be :—

$$\frac{1}{\frac{P+2\sqrt{P^2+2TP}}{3}} = \frac{3}{P+2\sqrt{P^2+2TP}}$$

A section through the warp would give a similar result, with the difference that T and P would change places; the threads per inch would therefore equal :—

$$\frac{3}{T+2\sqrt{T^2+2PT}}$$

These two expressions may be applied to any counts or diameters of yarns, provided such yarns are capable of being arranged as in the figure; but, as already suggested with reference to plain fabrics, the difference between the counts of the yarns should not be excessive, otherwise such yarns would be incapable of assuming the curvature and deflection consistent with the production of a balanced cloth. In the simplest case of the above three-leaf twill—*i.e.*, where P = T, the expression for threads as well as for picks per inch is :—

$$\frac{3}{T+2\sqrt{T^2+2TP}} = \frac{3}{T+2\sqrt{3T^2}} = \frac{3}{T+2T\sqrt{3}} =$$

$$\frac{3}{T(1+2\sqrt{3})} = \frac{3}{4{\cdot}464\,T} = 0{\cdot}672 \times \text{reciprocal of dia-}$$
meter.

Applying the above for the sake of example to a linen warp and weft of 22 leas, and a diameter equal to $\frac{1}{16} \times \frac{1}{\sqrt{22}} = \frac{1}{75}$ in., the result is :—

$$\frac{3}{4{\cdot}464 \times \frac{1}{75}} = \frac{3 \times 75}{4{\cdot}464} = 50{\cdot}4 \text{ threads and picks per inch;}$$

or, $0{\cdot}672 \times 75 = 50{\cdot}4$ threads and picks per inch.

It is desired again to point out that this formula should, in general, only be applied to cloths in which the warp and weft appear on the surface in equal quantities, and to approximately equal counts of warp and weft. The cloths made in the three-leaf twills are not in general balanced cloths. Ticking, for example, has almost invariably either a thicker warp than weft or more threads per inch than picks per inch. If, however, the respective numbers of threads and picks as well as the counts, are approximately equal, then the formula may be used with safety. The figures in the foregoing example of 22 leas are partly confirmed by the following analysis of a three-leaf ticking, which approximates to the above conditions. It contains 50 warp and 52 weft threads per inch, the respective counts being 20's and 25's lea, or an average of 22·5 leas and an average of 51 threads per inch.

Similar remarks may be applied to the yarn setting of three-leaf twilled jute fabrics, which, however, are generally composed of light warp and heavy weft. This arrangement is sufficient to cause them to be classed among those cloths where the warp does all the bending and the weft lies practically straight. In such a case the warp setting for a maximum cloth may be, as already indicated for plain fabrics of this character,

$$\frac{\text{Reciprocal of diameter}}{0 \cdot 7854}$$

Assuming a 9lbs. warp with a diameter of $\frac{1}{36}$in., then :—

$$\frac{36}{0 \cdot 7854} = 46 \text{ threads per inch;}$$

$$\text{or, } \frac{40 \text{ threads} \times 37\text{in.}}{6 \text{ threads per split} \times 20 \text{ splits per porter}} = 14 \text{ porter}$$

reed with three double threads per split.

This also is confirmed by practice. The maximum picks per inch for such a fabric would be :—

$$\frac{3}{2(T+P)+P}, \text{ or } \frac{3}{2T+3P}, \text{ as seen by S in Fig. 33.}$$

If it is assumed that the above is a 9lbs. warp and a 36lbs. weft, the latter with a diameter of $\frac{1}{18}$in., then :—

$$\frac{3}{2 \times \frac{1}{36} + 3 \times \frac{1}{18}} = \frac{3}{\frac{2}{36} + \frac{3}{18}} = \frac{3}{\frac{8}{36}} = \frac{108}{8} = 13\tfrac{1}{2} \text{ picks per inch.}$$

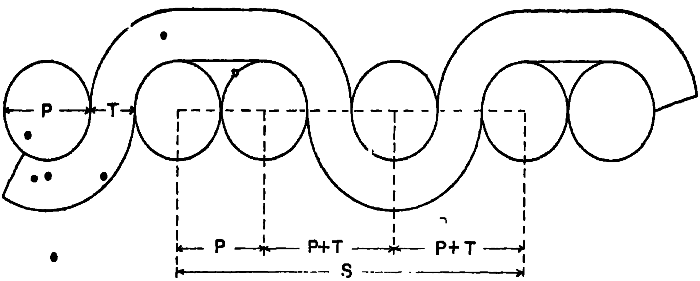


FIG. 33.

In the previous example of 3-leaf twilled jute sacking, and in all other similar examples where the setting of the warp equals or exceeds the reciprocal of the diameter of the yarn, it is evident that the whole width of the fabric, from selvage to selvage, is filled with warp yarn. Consequently these cloths do not show any open spaces, however few the picks per inch. In the theorectical balanced twill cloths, however, as in similar plain fabrics, the intersection of the weft with the warp causes a number of rectangular spaces through which light can penetrate. In all other balanced

fabrics these rectangular spaces diminish in proportion to the flattening of the threads and picks, till ultimately they disappear entirely.

The two extreme conditions are shown clearly in Figs. 34 and 35, the former illustrating a plan and two

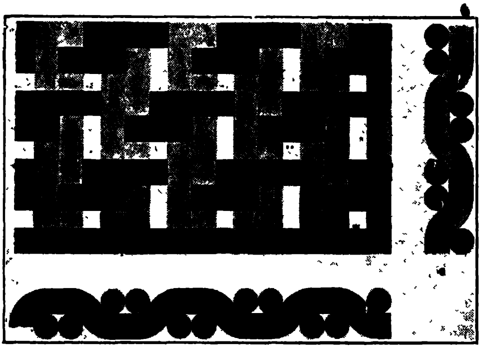


FIG. 34.

sections of the theoretical cloth $\frac{2}{2}$ twill, while the latter figure contains corresponding views of the actual cloth.

In considering this weave from a structural point of view it is evident that the space S, Fig. 36, which one

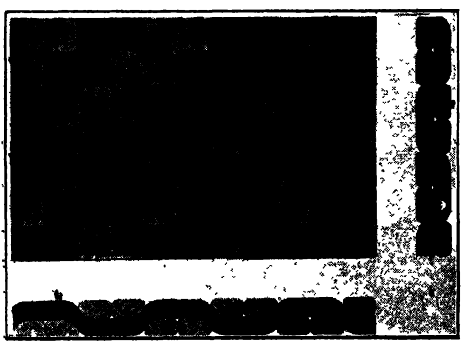


FIG. 35.

repeat of the weave occupies, is equal to $2P + 2\sqrt{P^2 + 2TP}$, where P and T represent the diameters of the weft and the warp. Since there are four picks in each repeat of the weave the average space occupied by each pick is :—

$$\frac{2P + 2\sqrt{P^2 + 2TP}}{4} = \frac{P + \sqrt{P^2 + 2TP}}{2}.$$

The maximum number of picks per inch for such a fabric should therefore be :—

$$\frac{1}{\frac{P + \sqrt{P^2 + 2TP}}{2}} = \frac{2}{P + \sqrt{P^2 + 2TP}},$$

and the maximum number of threads per inch

$$\frac{2}{T + \sqrt{T^2 + 2PT}}.$$

For the simplest case—*i.e.*, where the warp and the weft are equal in diameter—we have

$$\frac{2}{T + \sqrt{3T^2}} = \frac{2}{T + \sqrt{3}T} = \frac{2}{T(1 + \sqrt{3})} = \frac{2}{2 \cdot 732\,T}$$

$$= 0 \cdot 732 \times \text{reciprocal of diameter.}$$

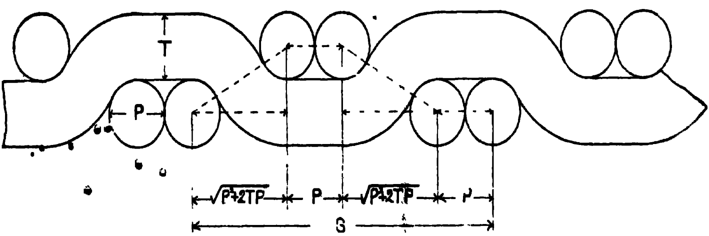


FIG. 36.

Thus, given a 10lbs. jute warp, with a diameter of $\frac{1}{108} \times \sqrt{10}$ = say, $\frac{1}{34}$in., we have $34 \times 0 \cdot 732 = 24 \cdot 88$, say 25 threads and picks per inch. In a sample of this

character which was woven with 26 threads per inch of 10·2lbs. per spyndle warp, considerable difficulty was experienced in obtaining from 23 to 24 picks per inch of 10lbs. weft, a fact which proves that the maximum condition was reached for this particular cloth.

The foregoing examples of $\frac{2}{1}$ and $\frac{2}{2}$ twills show that so far as a balanced fabric is concerned, any regular twill may be treated in a similar manner. Thus, in the 6-thread regular twill $\frac{3}{3}$, the total space S, Fig. 37, occupied by one repeat of the weave, equals $4\text{ D} + 2\sqrt{3} \times \text{D}$, assuming for simplicity that the warp and the weft are equal in diameter. The procedure is, as has already been shown, equally applicable to fabrics with warp and weft of different diameters, provided the yarns are capable of distributing themselves according to the conditions of a balanced cloth.

The average space occupied by each thread or pick in the above $\frac{3}{3}$ twill is $\frac{4\text{ D}+2\sqrt{3}\text{ D}}{6}$, and the threads or picks per inch equals

$$\frac{6}{4\text{ D} + 2\sqrt{3}\text{ D}} = \frac{3}{2\text{ D} + \sqrt{3}\text{ D}} = \frac{3}{\text{D}(2+\sqrt{3})} = \frac{3}{3\cdot732\text{ D}}$$

$$= 0\cdot804 \times \text{reciprocal of D.}$$

A further example of a fancy twill $\frac{1}{1}\frac{3}{2}\frac{4}{1}$ complete on 12 threads or picks is shown in Fig. 38. Here it is evident that $\text{S} = 6\text{ D} + 6\sqrt{3}\text{ D}$. The average space for each thread or pick therefore equals $\frac{6\text{ D}+6\sqrt{3}\text{ D}}{12}$, and the threads or picks per inch equals

$$\frac{12}{6\text{ D} + 6\sqrt{3}\text{ D}} = \frac{2}{\text{D} + \sqrt{3}\text{ D}} = \frac{2}{\text{D}(1+\sqrt{3})} = \frac{2}{2\cdot732\text{ D}}$$

$$= 0\cdot732 \times \text{reciprocal of D.}$$

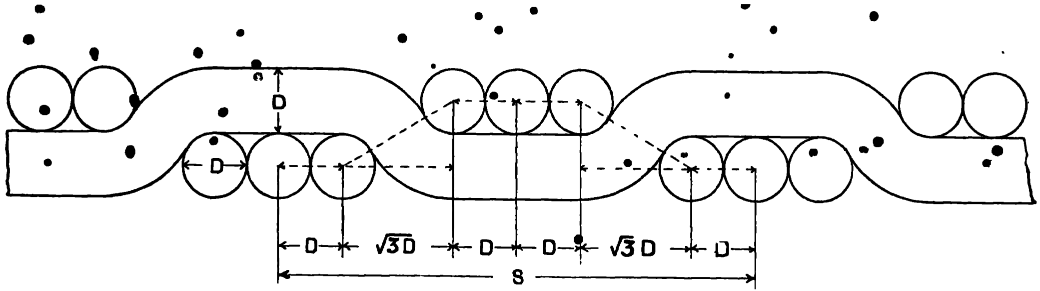


FIG. 37.

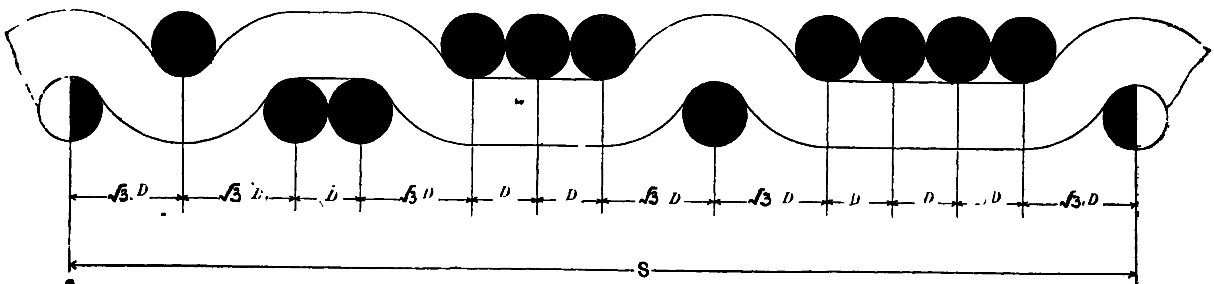


FIG. 38.

It will be observed from the foregoing that it is unnecessary to draw any diagram in order to find the number of threads or picks per inch. The numerator of the fraction (previous to cancelling) always indicates the number of threads or picks in one repeat of the weave; the first portion of the denominator is D $\times$ (threads minus intersections in one repeat), while the second portion of the denominator is $\sqrt{3}$ D $\times$ the number of intersections. Thus in the 10-thread twill $\frac{1}{1}\frac{4}{4}$ the numerator should be 10, while the denominator should be D $\times$ (10 − 4) = 6 D, and 4 $\sqrt{3}$ D or 6 D + 4 $\sqrt{3}$ D.

It is easily seen that there are four intersections, for the weave is divided into four portions. The expression for this weave is therefore :—

$$\frac{10}{6\,D + 4\sqrt{3}D} = \frac{5}{3\,D + 2\sqrt{3}\,D} = \frac{5}{D\,(3+2\sqrt{3})} = \frac{5}{6\cdot464\ D}$$

$$= 0\cdot773 \times \text{reciprocal of D.}$$

Again, in the weave $\frac{1}{2}\frac{3}{1}\frac{4}{3}$ there are for the maximum number of threads or picks :—

$$\frac{14}{8\,D+6\sqrt{3}\,D} = \frac{7}{4\,D+3\sqrt{3}\,D} = \frac{7}{D\,(4+3\sqrt{3})} = \frac{7}{9\cdot196\ D} =$$

$$0\cdot761 \times \text{reciprocal of D.}$$

In concluding this portion of our work, it is desired to point out that while the methods of calculation enunciated above are applicable in principle to all classes of balanced structures in plain or in regular twills, they will probably be found to be of most value when applied to those fabrics where the warp and the weft are virtually equal in count and diameter. In several instances it has been endeavoured to show how to calculate the numbers for maximum cloths of a non-

balanced structure, but in this class there is such a variety of possible cases that it is impossible to reduce them to any general formula which would be of any practical value. In certain classes of unbalanced fabrics—*e.g.*, linen damask, where the weave is such that the warp offers little resistance to the insertion of the weft—the picks per inch in many qualities regularly exceed the threads per inch by 50 per cent. Experience shows that in such cases the picks per inch may approach the reciprocal of the diameter of the weft yarn, but care should be taken not to attempt to exceed this number, for in most instances an unsatisfactory cloth would probably result.

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